POLLUTION PREVENTION PLANNING HANDBOOK

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This handbook is published for information only and should not be construed as providing any legal advice. For official legislative provisions, please consult the *Canadian Environmental Protection Act, 1999*, particularly Part 4.

Purpose

This handbook provides information about pollution prevention planning processes and techniques. Pollution prevention is the cornerstone of national efforts to manage toxic substances under the *Canadian Environmental Protection Act, 1999* (CEPA 1999). The Act authorizes the federal Minister of Environment to require pollution prevention plans for specific toxic substances. The guidance provided in this handbook is presented in a way that will help the reader comply with a requirement to prepare a substance-specific pollution prevention plan under CEPA 1999, but it may also be used in other circumstances, including to help implement pollution prevention in entire production lines and facility operations.

Those who are required to prepare a pollution prevention plan under CEPA 1999 are encouraged to read the *Guidelines for the Implementation of the Pollution Prevention Planning Provisions of Part 4 of the Canadian Environmental Protection Act, 1999 (CEPA 1999)* and *Pollution Prevention Planning Provisions of Part 4 of the Canadian Environmental Protection Act, 1999 – Frequently Asked Questions*. These documents are available on the CEPA Registry at www.ec.gc.ca/CEPARegistry/plans/p2 or may be obtained from Environment Canada's Inquiry Centre at 1-800-668-6767.

How to Use This Handbook

This handbook is divided into six sections. Together, they provide an overview of pollution prevention (P2), information on the P2 planning process, a model plan template, and detailed information on pollution prevention practices and certain analytical techniques for preparing a P2 plan. Each section and appendix can be read on its own or together with the others.

The process described in this handbook for developing and implementing a pollution prevention plan closely follows the procedures for developing an environmental management system (EMS) according to ISO 14001. Organizations with a formal EMS in place can develop and implement a pollution prevention plan within the framework provided by their EMS. These organizations may have already completed many of the steps outlined in this handbook.

This handbook presents generic advice on "best practices." While pollution prevention can provide significant benefits to organizations regardless of their size and nature of operations, the precise sequence, level of effort, scope of analysis and options reviewed may vary from facility to facility. Users of this handbook are therefore urged to adapt the information to their own circumstances and, where appropriate, seek advice from other companies that have implemented pollution prevention, from one of the many Internet-based resources supporting pollution prevention, from government officials or from qualified consultants.

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INTRODUCTION TO POLLUTION PREVENTION AND POLLUTION PREVENTION PLANNING

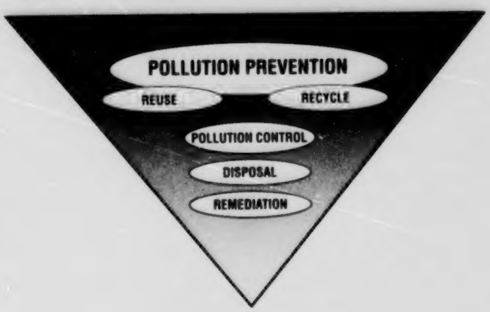
Primer on Pollution Prevention and Pollution Prevention Planning

WHAT IS POLLUTION PREVENTION?

The goal of environmental protection is to minimize adverse impacts on the environment from pollutants and waste. Pollution prevention (P2) is at the top of a hierarchy of environmental protection methods that also include reuse and recycling, pollution control or treatment, disposal and destruction, and remediation and clean-up (see Figure 1).[1] While all of these methods provide some environmental benefits, pollution prevention is at the top of the hierarchy because it can provide the most cost-effective opportunities for reducing environmental and health risk while improving a business's bottom line.

Pollution prevention seeks to eliminate the root causes of pollution, rather than treating the symptoms. It recognizes that pollutants and waste represent an inefficiency in the system and therefore relies on ***source reduction*** to address inefficiencies in the production of goods and services at their source. It encourages the kinds of changes that are likely to lead to lower production costs, increased efficiencies and more effective protection of the environment. By eliminating or reducing the ***causes*** of pollution and waste, risks to human health and the environment are reduced. By increasing the efficiency of production, avoiding accidental and operational releases, and reducing the non-productive costs of treatment and disposal, businesses can improve their financial bottom line and become more efficient and competitive.

Figure 1: Environmental Protection Hierarchy



Pollution prevention is defined as "the use of processes, practices, materials, products, substances or energy that avoid or minimize the creation of pollutants and waste, and reduce the overall risk to the environment and human health."

Source: *Canadian Environmental Protection Act, 1999*

For example, pollution prevention **usually**

- increases productivity through more efficient use of energy and raw materials;
- increases staff motivation through reduced worker risks and higher reliance on active worker participation in idea generation and implementation;
- reduces long-term liabilities that companies may face many years after pollution has been generated or disposed of at a given site;
- reduces the risk of environmental accidents; and
- is supported by employees, local communities, customers and the public.

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[1] In *A Strategy to Fulfil the CCME Commitment to Pollution Prevention* (1996), the Canadian Council of Ministers of the Environment (CCME) defines these practices as follows:
Reuse is the re-employment of products or materials, in their original form or in new applications, with refurbishing to original or new specifications as required.
Recycling is the extension of the effective life span of renewable and non-renewable resources through changes to processes, practices and the addition of energy inputs.
Pollution control or treatment is the addition of processes, practices, materials, products or energy to waste streams to reduce the risk posed by pollutants and waste before their release to the environment.
Disposal and destruction refer to secure placement or breakdown by thermal, chemical or other processes. These practices should only be applied to those pollutants and wastes that are not amenable to pollution prevention or treatment.
Remediation and clean-up activities are "last resort" elements of environmental protection. Remediation is the use of processes, practices, materials, products or energy to restore to a healthy state ecosystems that have been damaged by human activity. It is often the most expensive and least efficient method of environmental protection.

Pollution prevention **often**

- increases profitability and lowers production costs by avoiding or reducing pollution control, waste treatment and disposal costs;
- reduces consumer risks associated with products containing hazardous substances;
- avoids regulatory compliance costs;
- provides evidence of due diligence;
- leads to insurance savings;
- provides enhanced access to capital from financial institutions and lenders; and
- requires little capital investment or provides a rapid to moderate return on any capital or operating investments required.

WHAT IS POLLUTION PREVENTION PLANNING?

Pollution prevention planning is a systematic, comprehensive method of identifying options to minimize or avoid the creation of pollutants or waste. CEPA 1999 has provisions that allow the federal government to require the development and implementation of pollution prevention plans for specific toxic substances. Pollution prevention planning, however, can be more broadly applied to an entire production process or facility.

Plans can focus on a single pollutant or on multiple pollutants. Many P2 plans also cover water and energy use. The more comprehensive it is in scope, the more likely it is that the planning process will focus on the root causes of the problem, identify the most cost-effective pollution prevention opportunities and avoid inappropriate trade-offs (such as substituting one toxic substance for another). Plans should be tailored to the needs of the organization, forming an integral part of its existing business plan.

The P2 planning process itself also has its own results and benefits. For example:

- A careful planning process ensures the selection and implementation of the most cost-effective pollution prevention options.
- Systematic planning ensures that pollution prevention objectives and activities are consistent with the objectives and activities identified in the organization's broader planning processes.
- Effective pollution prevention planning informs and assists broader business planning investment analysis and decision making (such as capital budgeting and purchasing).
- A documented pollution prevention plan may be a condition for receiving financing or insurance at improved rates.

There are six key steps to developing and implementing a pollution prevention plan:

Step 1: Establish a commitment to pollution prevention and an overall pollution prevention policy.
Step 2: Conduct a baseline review to identify current levels and sources of inputs (raw materials, energy and water), products and non-product outputs, and information gaps associated with a facility, specific product(s) or production line(s).
Step 3: Develop the plan: set objectives and targets and identify, evaluate and select pollution prevention options to meet the objectives and targets selected.
Step 4: Implement the plan.
Step 5: Monitor implementation.
Step 6: Evaluate, review and improve the plan.

These steps are described in more detail in Section II, "How to Prepare a Pollution Prevention Plan."

COMMONLY APPLIED POLLUTION PREVENTION PRACTICES

There is a wide range of pollution prevention practices. Six of the most common and effective practices are described below. For more detail on these practices, please refer to the corresponding appendices.

Product design and reformulation includes methods for preventing the pollution associated with the entire life cycle (i.e., resource extraction, production, use and disposal) of products through the design of new products and the redesign or reformulation of old ones. The product design stage is a crucial starting point for implementing pollution prevention. Addressing environmental concerns from the earliest stage is a cost-effective way to avoid environmental impacts throughout the product life cycle. "Design for environment" (DfE) seeks to integrate environmental criteria into the usual design considerations of performance, cost, quality, cultural, legal and technical criteria. In seeking to reduce the environmental impacts of producing and consuming products and to improve efficiencies over the entire life cycle, DfE can involve reducing the toxicity of a product, reducing the amount of waste material, extending the life of a product, extending the life of the materials used, improving the selection of materials, and reducing the energy and material intensity required to produce, use and dispose of the product. For more information and guidance, please see Appendix D.

Equipment modifications and process changes introduce new technologies or approaches to existing operating systems, processes and practices to improve production efficiencies and reduce pollution generated and materials, energy or water wasted. This practice can include, for example, replacing solvents for paint or varnish removal with mechanical stripping; using ion-based painting systems; or integrating recirculation or countercurrent cleaning within a process. For more information and guidance, please see Appendix E.

Materials and feedstock substitution entails replacing polluting materials used in the production process or embedded within a product with non-polluting or less polluting materials and feedstock. Also referred to as source elimination, materials substitution aims to decrease or eliminate the quantity of toxic, hazardous or polluting materials used, thereby lowering the risks of harmful exposure to workers, consumers, communities and the environment. Opportunities for materials substitution are broad, and include painting applications, parts cleaning, metal finishing, printing operations, building and grounds maintenance, among others. For more information and guidance, please see Appendix F.

Operating efficiencies and training are important elements of most companies' ongoing activities. In many cases, an existing focus on improving operating efficiencies can provide a very cost-effective way to prevent pollution and reduce costs or improve quality. These multiple objectives can often be achieved through basic improvements in work procedures, such as changing production schedules to minimize equipment and feedstock changeovers, improving maintenance scheduling, segregating by-products at source, training and encouraging staff to improve materials handling and to recognize pollution prevention opportunities, and implementing good housekeeping practices. In many cases, operational efficiencies can be implemented relatively easily through the introduction of work procedures that target process control systems. The result is often improved productivity, increased reliability, more efficient resource and energy use, and reduced waste of financial and production materials and resources. For more information and guidance, please see Appendix G.

Purchasing techniques and inventory management includes two distinct practices. ***Environmentally preferable purchasing*** involves the integration of environmental considerations into existing and new purchasing practice. By building environmental issues into the purchasing process, organizations can reduce material and energy consumption, avoid unnecessary use of toxic substances in their products, minimize waste generation, and in many cases reduce associated costs. ***Environmentally responsible inventory management*** entails the incorporation of environmental considerations into inventory management systems. Examples of these techniques include just-in-time delivery, avoidance of unnecessary waste generation by ensuring that materials do not stay in inventory beyond their shelf life, and quality control for feedstocks to prevent production of "off-spec" products. For more information and guidance, please see Appendix H.

On-site reuse and recycling cover the processes of reusing and recycling at the same place where an activity has taken place. ***Reuse*** is the re-employment of products or materials in their original form or in new applications, with refurbishing to original or new specifications as required. ***Recycling*** is the extension of the effective life span of renewable and non-renewable resources through changes to processes or practices and the addition of energy inputs. When it is conducted in an environmentally sound manner, recycling is preferable to end-of-pipe treatment. Effective reuse and recycling requires a different perspective, which views non-product outputs (waste) as a loss of valuable process materials that, if reused or recycled, could have significant environmental and economic benefits. Materials that can typically be reused and recycled include raw materials, chemicals and treated and untreated wastewater. Specific examples of process changes include recovering metals by ion exchange or reverse osmosis; recycling cooling water; and reusing trim and cuttings from paper making or plastics moulding in on-site production, rather than sending the trim off-site for waste disposal. For more information and guidance, please see Appendix I.

In some cases, pollution prevention can be enhanced by co-operative action among two or more facilities. For example, neighbouring facilities in unrelated businesses or activities can co-operate either by developing joint infrastructure or by arranging themselves so that one company uses the other's non-product output as an input. Known as "industrial ecology," these types of co-operative initiatives can be valuable, particularly where on-site pollution prevention options are not feasible. In many cases, however, organizations will have opportunities to implement pollution prevention through simple and cost-effective methods that are within the control of the plant manager.

HOW TO PREPARE A POLLUTION PREVENTION PLAN

Effective Pollution Prevention Planning, Implementation and Review

This section is divided into two parts. The first part describes each of the six key steps in developing an effective pollution prevention plan. These steps are based on the plan-do-check-act methodology typically used within an EMS. The second part describes how a pollution prevention plan fits within an EMS, and ways in which an existing EMS can be enhanced to facilitate the development of a P2 plan.

This section also refers to the model pollution prevention plan that is described in detail in Appendix A. The purpose of this model plan is to provide a template that can be used for preparing and documenting a P2 plan. It has been designed to help organizations compile, analyze and present information on the sources, risks and impacts associated with the use, generation and emission of toxic substances and other pollutants and wastes.

This model plan will be useful both to organizations required to prepare a pollution prevention plan under CEPA 1999 and to organizations developing pollution prevention plans for other reasons. In addition to supporting the development of a P2 plan, it can be used to help generate information to:

- complete the Declarations of Preparation and Implementation, and Interim Progress Reports for pollution prevention plans required under Part 4 of CEPA 1999;
- meet reporting requirements of other regulations;
- document the anticipated and actual benefits from implementing pollution prevention, including financial savings;
- provide documented evidence that an organization is committed to prevention of pollution as required by ISO 14001; or
- meet the requirements of third parties (such as financial institutions or customers).

The information presented in this section and in the model plan represents generic advice on "best practices." While pollution prevention can provide significant benefits to organizations regardless of their size and nature of operations, the precise sequence, level of effort, scope of analysis and options reviewed may vary from facility to facility. Each organization should adapt this advice to its own circumstances.

POLLUTION PREVENTION PLANNING STEPS

Table 1 summarizes the six main steps to follow in developing and implementing a pollution prevention plan. The remainder of this section describes each step in greater detail. Where appropriate, the left-hand column cross-references the relevant parts of the model plan and relevant appendices.

Table 1: Pollution Prevention Planning Checklist

Step	Status
1. Commitment and Policy	
• Obtain senior management commitment	
• Prepare and communicate a written pollution prevention policy	
• Assign an accountable manager	
• Establish a pollution prevention planning team and commit adequate resources	
• Integrate the pollution prevention planning process with existing management systems, including any EMS	
2. Baseline Review	
• Define the system boundaries (scope) of the plan	
• Assess the existing situation (with good baseline information)	
• Establish a process and material flow profile of relevant operations and processes	
• Quantify inputs and outputs and mass balance	
• Calculate total costs and benefits of current approaches	
• Identify relevant legal requirements (international, federal, provincial, municipal)	
• Identify related company policies and targets	
• Identify stakeholder concerns and market issues	
• Identify business issues including the existing planning and management systems	
3. Planning	
• Identify pollution prevention opportunities	
• Establish objectives, targets and performance indicators	
• Define and involve the affected community and employees	
• Develop an action plan to meet objectives and targets	
• Identify specific pollution prevention options, and their environmental, technical and cost aspects	
• Evaluate and rank options based on environmental benefits, technical feasibility, costs and applicable strategic considerations	
• Select preferred options and assign responsibilities, resources and timelines	
4. Implementation	
• Implement the selected options	
• Identify employee training needs and provide training	
• Integrate with existing management systems	
• Create support mechanisms (e.g., incentives, penalties, internal and external communications, reporting forms)	
5. Monitoring and Reporting	
• Monitor implementation of the plan and performance against objectives and targets	
• Document the results, including costs, savings and other benefits	
• Take corrective action if necessary	
• Report to management and to the public	
6. Review, Evaluation and Improvement	
• Conduct regular reviews of implementation progress and performance results	
• Identify changing internal and external circumstances	
• Revise the objectives and targets, resource allocation and action plan as required	

Step 1: Commitment and Policy

Model Plan Items:
2 Statement of CEO
3 Corporate Environmental Policy
4.3 Overall Objectives

To get the most out of pollution prevention planning, the broad support and commitment of senior management and all staff to a policy of preventive environmental management and superior environmental performance is essential. This starts with top management commitment, which should be expressed through a written and formally adopted pollution prevention policy or a specific commitment to P2 within an existing environmental policy statement.

Accountability for leading the pollution prevention program should be assigned to a senior manager. This assignment should be accompanied with sufficient authority and resources to assemble a pollution prevention planning team, gather the necessary information, and implement the selected P2 options. The pollution prevention planning team should include representatives from principal operating divisions, including purchasing; research, design and development; product management, shipping and receiving; industrial engineering; production; marketing; maintenance; and environment, health and safety.

In many cases, it will be possible to work with an existing "green team" or environmental, health and safety committee, rather than create a new pollution prevention team. Beyond the pollution prevention planning team, employees from all parts of the organization should be informed about and directly engaged in the program. Process operators, in particular, know the production process intimately and often offer excellent insights into pollution prevention opportunities and options.

Because a pollution prevention plan can be fully integrated into an EMS, some organizations may choose not to produce a separate pollution prevention plan. This level of integration can help to incorporate pollution prevention principles and practices into standard business practice.

Other organizations may choose to produce a separate pollution prevention plan to meet specific external requirements (such as regulatory requirements) or internal needs (for example, to highlight the organization's commitment to pollution prevention, particularly if it is a new emphasis). In these instances, the pollution prevention plan should be closely aligned with the EMS, and elements of the P2 plan (such as the objectives and targets, action plans, and roles and responsibilities) should be directly incorporated into the EMS documentation.

Step 2: Baseline Review

Model Plan Item:
5 Baseline Review

The baseline review provides the detailed information required to identify and address an organization's most significant pollution prevention opportunities and information gaps. Pollution prevention planning requires an in-depth knowledge of production and/or product life cycle processes. The baseline review is a systematic approach to building that knowledge, and collecting the information necessary to identify pollution prevention opportunities.

The first step in the baseline review should be to define the system boundary within which the plan will focus. Will it consider a specific functional area or process, and will it be circumscribed to within the plant gates, or will it also include off-site disposal impacts, suppliers and product impacts? The decision on where the system boundary should be set is an important one, because it will strongly influence the subsequent identification of pollution prevention opportunities and options. For example, if the greatest environmental impact of a product comes at the end-of-life stage, but the system boundary includes only the manufacturing stages, it is unlikely the plan will lead to the consideration of product design and reformulation as pollution prevention options.

In choosing the system boundary, consideration should therefore be given to which stages in the life cycle of a product, process or service cause the greatest environmental impacts (extraction or processing of raw materials and inputs, product manufacturing, product use, or end of life).

The review itself starts by building a detailed profile of the relevant production process and all associated inputs, products and non-product outputs (losses). It then quantifies these flows, and uses materials accounting or a materials mass balance to check that all losses have been identified.

Consideration should be given to each major non-product output stream, as well as known or suspected sources of pollution, and to a clear understanding of their root causes. For on-site losses, this analysis often can be assisted by a facility walk-through and by discussions with plant employees and pollution prevention practitioners in the industry. More detailed life cycle analysis may be required to analyze the pollution associated with the use or disposal of products.

Appendix B:
Key Elements of a
Baseline Review

Appendix B provides more detailed guidance on conducting a baseline review. It describes techniques for creating flow diagrams, compiling input/output inventories, doing materials accounting and calculating mass balances.

In addition to examining current material flows, the pollution prevention planning team should also identify other internal and external factors that will influence the selection of pollution prevention options. Such factors could include:

- current and anticipated legal requirements in all applicable jurisdictions;
- issues or concerns raised by stakeholders, including the local community, financial institutions, customers, regulators, industry associations and suppliers; and
- internal policies and procedures that affect products and processes that may be targeted by pollution prevention options. These could include, for example, quality management systems, policies regarding off-spec products, import and export policies, health and safety programs, and the organization's EMS.

Step 3: Planning

Model Plan Items:

4.1 Scope of the Plan

4.2 Timing

4.3 Overall Objectives

4.4 P2 Targets

6 Identification and Evaluation of P2 Options

7 Implementation Plan

Ideally, the planning step would follow a clear sequence:

- Drawing on the baseline information identified in Step 2, identify pollution prevention opportunities – opportunities, for example, to improve environmental and/or economic performance resulting from the identification of the use of toxic substances, the creation of non-product outputs, continuous or episodic losses of material or energy or any other environmental concerns.
- Establish pollution prevention objectives and targets and performance indicators.
- Identify, evaluate, rank and select pollution prevention technical options for achieving the targets by focusing on the root causes of the opportunities identified.
- Select options, finalize targets and indicators, and schedule actions for implementation.

Inevitably, however, the planning step is an iterative process that builds on the opportunities identified as a result of the baseline review, establishes tentative objectives and targets, and refines those objectives and targets through the detailed evaluation of specific options.

Objectives, targets and options should be identified to **prevent** both:

- the pollution that is or could be caused by the organization (i.e., ***on-site releases*** and ***off-site transfers for disposal and recycling***); and
- the pollution that is or could be associated with ***pollutants contained in products*** that are distributed or sold off-site.

Pollution prevention objectives and targets should be specific, measurable, realistic and time-based, and should reflect the opportunities identified in the baseline review.

To establish realistic objectives and targets, it is also important to have an understanding of what pollution prevention changes are feasible for a particular process or substance. This requires considering the applicability and potential impact of a broad range of P2 practices. Options can be generated through brainstorming sessions, employee suggestions and consultations with outside sources of information or expertise.

Different pollution prevention practices may be required to address different types of issues. In order to ensure that the options considered address the root causes of the pollution problem, it is desirable to consider the full life cycle of a product. For simplicity, the ***life cycle of a product*** may be categorized into six stages:

- design;
- raw material acquisition and processing;
- manufacturing and production;
- filling, packaging and distribution;
- use, reuse and maintenance; and
- disposal.

Table 2 lists possible objectives and pollution prevention practices that should be considered when addressing issues arising at each of these different life cycle stages.

For each potential pollution prevention opportunity or groups of opportunities, options should be evaluated on the basis of technical feasibility, environmental effectiveness, cost effectiveness and other business considerations relevant to each organization.

- From a **technical** perspective, the issue is whether the option is feasible. This evaluation may include criteria such as availability and proven performance of a technology; impacts on product quality; risk of non-performance; ease of implementation; maintenance requirements; compatibility with existing space, technical systems and support systems; health and safety implications; labour, skills and training requirements; effect on operational flexibility; and shutdown requirements for implementation.
- In addition to estimating the potential **environmental benefits** of each option, it is important to account for possible **adverse impacts**. Environmental criteria should be selected to determine the magnitude of both types of impacts. For example, are there impacts on other media? Does a reduction in generation of air emissions, for instance, result in an increase in hazardous waste or effluent production? Are there changes to the amount of energy or water required, or changes to the type or quantity of raw materials required? Are there changes to the treatability of wastes?
- **Financial considerations** require analysis of the differences between the costs of the current process and the projected costs of proposed options. In many cases, the options reviewed may actually reduce overall production costs. Often, some form of total cost accounting (TCA) can be helpful to estimate all relevant costs, savings and other benefits. TCA methods rely on activity-based costing to disaggregate important indirect and hidden costs that might otherwise be lumped into overhead accounts. Appendix C provides more detailed information on evaluating the costs and benefits of pollution prevention options and comparing them to the baseline situation and to other options.
- Finally, **business considerations** may render certain evaluation criteria more important than others, or elevate the priority of a specific reduction option. These may include such factors as legal considerations, regulatory and market trends likely to influence future operations, social and cultural issues, corporate image, and opportunities for partnerships, shared learning and synergies.

Appendix C:
Assessing the Costs and Benefits of Pollution Prevention Options

Turning the pollution prevention plan into action requires commitment from all parties involved, adequate human resources (including technical expertise), a sufficient budget and a clear and realistic implementation schedule. Not all feasible options will be selected, and not all are likely to be scheduled for implementation in the first year. Some may need to be sequenced or phased in. Based on the evaluation considerations listed above, pollution prevention options can be ranked, preferred initiatives selected and an implementation schedule established. In some cases, cost savings from one set of initiatives can help to finance a next generation of initiatives.

Appendices:

D Product Design and Reformulation

E Equipment Modifications and Process Changes

F Materials and Feedstock Substitution

G Operating Efficiencies and Training

H Purchasing Techniques and Inventory Management

I On-Site Reuse and Recycling

Table 2: Possible Pollution Prevention Objectives and Practices

Stage Within the Life Cycle of a Product	Possible Objectives	Possible Practices
Design	**Reduce material intensity** **Extend product life** **Reduce pollutants from product use**	• Product design and reformulation (Appendix D)
Raw material acquisition and processing	**Increase use of low-impact materials** • Renewable, non-hazardous, less toxic, low energy content, recycled and/or recyclable **Reduce materials** • Reduce weight • Reduce storage volume • Reduce transport volume • Reduce number of different materials	• Product design and reformulation (Appendix D) • Materials and feedstock substitution (Appendix F) • Purchasing techniques and inventory management (Appendix H)
Manufacturing and production	**Increase clean production** • Low and clean energy use • Water conservation • Low waste • Few and clean inputs	• Equipment modifications and process changes (Appendix E) • Operating efficiencies and training (Appendix G) • On-site reuse and recycling (Appendix I)
Filling, packaging and distribution	**Use efficient and clean distribution** • Minimum packaging • Low-impact packaging • Low-impact transport	• Product design and reformulation (Appendix D) • Materials and feedstock substitution (Appendix F) • Operating efficiencies and training (Appendix G)
Use, reuse and maintenance	**Minimize user impact** • Low energy use • Clean energy use • Low water use • Low material use and waste generation • Low emissions **Optimize initial life** • Adaptable and upgradable • Reliable and durable • Easily maintained and repaired	• Product design and reformulation (Appendix D) • Materials and feedstock substitution (Appendix F)
Disposal	**Optimize end-of-life** • Ensure that product is reuseable, remanufacturable, recyclable or safely disposable	• Product design and reformulation (Appendix D) • Materials and feedstock substitution (Appendix F)

The evaluation method, and the reasons for selecting certain options over others, should be documented for reference during refinement of action plans.

For each option selected, an action plan should be developed that identifies the specific targets to be met, tasks required to achieve the target (including training), the responsible party or parties, all affected parties, the resource requirements, the estimated date of completion and appropriate indicators for monitoring.

The contribution of employees to the integration of new ideas into the plan should not be underestimated. Staff with experience working on the shop floor, for example, may have innovative contributions to housekeeping, equipment modification and production line changes.

Finally, the achievement of certain objectives and targets may require the collaboration of external parties, such as suppliers or customers. If this is the case, it is important to engage these parties throughout the development and implementation of the pollution prevention plan.

Step 4: Implementation

Model Plan Item:
7 Implementation Plan

Implementing the pollution prevention plan requires a concerted effort by management and employees. While various individuals will have the lead responsibility for different initiatives, it will be important for one person to oversee implementation.

The pollution prevention plan is more likely to be successful if employees are aware of the plan and of how they can contribute to its achievement. Employees may require specific training. For example, operators may require training in the operation of new equipment, or on operating procedures designed to reduce waste.

Beyond specific training requirements, all employees should be made aware of the plan and kept informed of actions taken and progress made. This can be done through company newsletters, updates provided by supervisors at regular shift or staff meetings, pay cheque inserts, or special meetings or celebrations to mark the kick-off or to recognize special pollution prevention achievements. Employee incentive programs can also be used to encourage active participation in meeting pollution prevention targets.

Step 5: Monitoring and Reporting

Model Plan Item:
8 Monitoring and Reporting

A monitoring plan should describe how the organization intends to monitor:

- the status of implementation of the pollution prevention plan, including related costs and savings; and
- progress toward achieving objectives and targets.

The plan should identify appropriate monitoring methods, responsible staff and monitoring frequency. For each target and objective, specific performance indicators should be identified to measure progress over time.

It can be very difficult to develop a single performance indicator that captures all of the relevant information. In many cases, it is advisable to develop a set of indicators addressing such factors as the absolute quantity of pollutants and waste avoided or prevented; the quantity avoided or prevented as a percentage of throughput; costs; savings; and payback periods. Indicators such as the number of public complaints received can also be useful in some cases.

Monitoring should be conducted on a regular basis to ensure that deviations from original objectives and targets are detected and corrected at an early stage. When measuring reductions in the absolute or per-unit consumption of a substance or material, use the same measurement method as that used to calculate the baseline. Document the methods used and the frequency of measurement, and ensure responsible employees are trained in these techniques. Monitoring and measurement records should be kept on file to provide a historical record. A corrective action program should be in place to identify the need for changes based on the monitoring results and to ensure appropriate action is taken to address the root cause of any noted deficiencies.

Progress reports are valuable tools for maintaining momentum and evaluating whether the program is meeting its goals. Reporting progress can help senior managers determine whether any corrective action is necessary. It is also useful to track financial information, so that managers know if initial cost assessments were accurate and whether any savings have been achieved.

Public reporting also serves a valuable accountability function. For example, public reporting can be essential to ensuring that the organization receives the full benefits of an effective pollution prevention plan, including enhanced market image, improved community and government relations and easier access to financing.

The evaluation method, and the reasons for selecting certain options over others, should be documented for reference during refinement of action plans.

For each option selected, an action plan should be developed that identifies the specific targets to be met, tasks required to achieve the target (including training), the responsible party or parties, all affected parties, the resource requirements, the estimated date of completion and appropriate indicators for monitoring.

The contribution of employees to the integration of new ideas into the plan should not be undervalued. Staff with experience working on the shop floor, for example, may have innovative contributions to housekeeping, equipment modification and production line changes.

Finally, the achievement of certain objectives and targets may require the collaboration of external parties, such as suppliers or customers. If this is the case, it is important to engage these parties throughout the development and implementation of the pollution prevention plan.

Step 4: Implementation

Model Plan Item:
7 Implementation Plan

Implementing the pollution prevention plan requires a concerted effort by management and employees. While various individuals will have the lead responsibility for different initiatives, it will be important for one person to oversee implementation.

The pollution prevention plan is more likely to be successful if employees are aware of the plan and of how they can contribute to its achievement. Employees may require specific training. For example, operators may require training in the operation of new equipment, or on operating procedures designed to reduce waste.

Beyond specific training requirements, all employees should be made aware of the plan and kept informed of actions taken and progress made. This can be done through company newsletters, updates provided by supervisors at regular shift or staff meetings, pay cheque inserts, or special meetings or celebrations to mark the kick-off or to recognize special pollution prevention achievements. Employee incentive programs can also be used to encourage active participation in meeting pollution prevention targets.

Step 5: Monitoring and Reporting

Model Plan Item:
8 Monitoring and Reporting

A monitoring plan should describe how the organization intends to monitor:

- the status of implementation of the pollution prevention plan, including related costs and savings; and
- progress toward achieving objectives and targets.

The plan should identify appropriate monitoring methods, responsible staff and monitoring frequency. For each target and objective, specific performance indicators should be identified to measure progress over time.

It can be very difficult to develop a single performance indicator that captures all of the relevant information. In many cases, it is advisable to develop a set of indicators addressing such factors as the absolute quantity of pollutants and waste avoided or prevented; the quantity avoided or prevented as a percentage of throughput; costs; savings; and payback periods. Indicators such as the number of public complaints received can also be useful in some cases.

Monitoring should be conducted on a regular basis to ensure that deviations from original objectives and targets are detected and corrected at an early stage. When measuring reductions in the absolute or per-unit consumption of a substance or material, use the same measurement method as that used to calculate the baseline. Document the methods used and the frequency of measurement, and ensure responsible employees are trained in these techniques. Monitoring and measurement records should be kept on file to provide a historical record. A corrective action program should be in place to identify the need for changes based on the monitoring results and to ensure appropriate action is taken to address the root cause of any noted deficiencies.

Progress reports are valuable tools for maintaining momentum and evaluating whether the program is meeting its goals. Reporting progress can help senior managers determine whether any corrective action is necessary. It is also useful to track financial information, so that managers know if initial cost assessments were accurate and whether any savings have been achieved.

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Model Plan Item:
9 Review and Evaluation

Step 6: Review, Evaluation and Improvement

Pollution prevention is a way of doing business, and success cannot be measured by reference to a single reduction target. Pollution prevention plans should therefore be continuously improved, providing ongoing environmental and economic benefits to committed organizations.

Senior management should review the pollution prevention program's achievements on a regular basis, evaluate whether objectives and targets are still appropriate, determine if the plan is meeting these objectives, and decide whether corrective action or improvements are necessary. For organizations with a formal EMS in place, the pollution prevention program can be reviewed within the scope of the EMS management review.

In order to make effective decisions concerning pollution prevention activities, senior management should be provided with progress reports (see Step 5), along with any additional information on changing internal or external circumstances that may impact the selection and implementation of pollution prevention options. For example, changes in technology, finances or strategic considerations may make options feasible that previously were not. Similarly, the organization's growing experience with pollution prevention may lead to the identification of new pollution prevention opportunities. Based on this review, senior management may identify a need for resource reallocation, revisions to the action plan or changes to the pollution prevention objectives and targets.

Finally, just as effective implementation requires the close involvement of employees, ongoing evaluation results should be widely shared within the organization. This will enhance employee "ownership" of and commitment to pollution prevention, and can lead to the generation of new ideas and suggestions for refinements and improvements.

Integrating Pollution Prevention Planning Within an Environmental Management System

Many organizations have an environmental management system (EMS) in place. For these organizations, pollution prevention planning can be readily integrated within their EMS to improve environmental performance, reduce duplication, and ensure that their pollution prevention plan supports the environmental objectives and targets established in their EMS.

The ISO 14001 standard, *Environmental Management Systems – Specification with guidance for use*, defines an EMS as the part of the management system that includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy.

While an EMS is broader in scope than a pollution prevention plan, an existing EMS may provide certain elements that can serve as the building blocks for a pollution prevention plan. Organizations that have an EMS in place but that have not previously implemented pollution prevention practices in a systematic way will not have to start from scratch. Rather, they can build their pollution prevention plan within the framework provided by their EMS.[2] For example:

- **The environmental review completed during development of an EMS can provide part of the baseline information required for a pollution prevention plan.** During development of its EMS, an organization typically conducts a review of its operations, products and services and identifies those aspects that have the potential to impact the environment. In developing a pollution prevention plan, the organization can use this review to help establish the baseline information required to select pollution prevention targets and options. It can also use this information to help determine which substances, processes, and/or products and services to focus its pollution prevention efforts on.
- **Pollution prevention objectives, targets and actions can build on existing objectives, targets and action plans identified within the EMS.** An organization with an EMS in place should review its commitments and action plans to ensure that, where possible, the actions and approaches identified are consistent with pollution prevention. Some objectives, targets and action plans may serve as the basis for the pollution prevention plan; others may need to be modified to incorporate pollution prevention concepts; and, in some cases, new objectives, targets and actions may be required.
- **Monitoring and reporting of the pollution prevention plan can be done through existing systems.** An EMS establishes procedures for regularly monitoring and reporting to senior management. By incorporating pollution prevention objectives, targets and action plans into its EMS, an organization should be able to monitor and report on progress toward these commitments through its existing management systems (e.g., corrective action program, regular management reviews).

When developing a pollution prevention plan, organizations with an existing EMS should therefore review each element of their EMS to determine how pollution prevention principles and practices can be incorporated. Table 3 identifies how pollution prevention can be incorporated into the EMS elements identified in *ISO 14001 – The International Standard on Environmental Management Systems*.

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Table 3: Integrating Pollution Prevention into an EMS

ISO 14001 EMS Elements	Specific Guidance on Integrating Pollution Prevention
4.2 Environmental Policy	Within the Environmental Policy, commit to the principle of pollution prevention and to favour pollution prevention practices where feasible.
4.3.1 Environmental Aspects	Use the initial environmental review conducted as part of EMS development to identify significant environmental aspects that should be the focus of the pollution prevention plan. Ensure scope of EMS and scope of pollution prevention plan are consistent, or document differences.
4.3.2 Legal and Other Requirements	Reference any legal requirement to prepare a pollution prevention plan (e.g., CEPA 1999, etc.) if applicable, or state voluntary commitment.
4.3.3 Objectives and Targets	Revise existing objectives and targets to emphasize pollution prevention over pollution control; add additional objectives and targets specific to pollution prevention, if appropriate.
4.3.4 Environmental Management Program(s)	Revise environmental management programs and action plans to incorporate pollution prevention practices.
4.4.1 Structure and Responsibility	Designate a pollution prevention manager and establish a pollution prevention team. Clearly assign roles, responsibilities and accountability. Members could overlap with the EMS team/co-ordinator.
4.4.2 Training, Awareness and Competence	Ensure appropriate staff receive training on pollution prevention concepts, pollution prevention practices applicable to their duties, and any new or revised targets and operating procedures.
4.4.3 Communication	When communicating progress toward achieving objectives and targets, include progress toward pollution prevention objectives and targets.
4.4.4 EMS Documentation	Reference the pollution prevention plan and associated procedures and records within EMS documentation.
4.4.5 Document Control	Document control procedures should cover the pollution prevention plan and associated procedures and records.
4.4.6 Operational Control	Revise operating procedures as appropriate to include pollution prevention techniques. Certain pollution prevention targets may require revisions to specific operating procedures or development of new procedures.
4.4.7 Emergency Preparedness and Response	Ensure emphasis is placed on emergency prevention within this procedure and within operational controls.
4.5.1 Monitoring and Measurement	Existing monitoring and measurement procedures should be followed (and revised, as required) to monitor progress toward achieving pollution prevention objectives and targets.
4.5.2 Non-conformance and Corrective and Preventive Action	Pollution prevention should be an important element of *preventive* action process.

Table 5: Integrating Pollution Prevention into an EMS

ISO 14001 EMS Elements	Specific Guidance on Integrating Pollution Prevention
4.5.3 Records	Maintain records related to development, implementation and maintenance of the pollution prevention plan in accordance with record management procedures.
4.5.4 EMS Audit	If the pollution prevention plan is integrated within the EMS, the scope of the EMS audit will include all elements of the pollution prevention plan.
4.6 Management Review	Management review should include a review of progress toward achieving pollution prevention-related objectives and targets, and any factors preventing their achievement (internal and external barriers).

ISO 14001 – The International Standard on Environmental Management Systems **encourages companies to include a formal commitment to the prevention of pollution within their environmental policy statements. There is, however, an important difference between the definition of pollution prevention in CEPA and the term "prevention of pollution" used in ISO 14001. CEPA defines pollution prevention as the "use of processes, practices, materials, products, substances or energy that avoid or minimize the creation of pollutants and waste and reduce the overall risk to the environment or human health." The CEPA definition of pollution prevention does not include pollution control, treatment and off-site recycling. The term "prevention of pollution" in the ISO 14001 includes these methods. Canadian environmental policy gives priority to pollution prevention actions and recommends the use of recycling and pollution control only where pollution prevention is not feasible.**

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GLOSSARY

At-source separation, the physical separation of materials at their point of use or generation in the production facility in order to recover and minimize process wastes. Appendix I.

Baseline review, a general survey or assessment of an organization's operations, processes and products that provides the detailed baseline information required to develop a pollution prevention plan. Typically entails a review of the inputs, products and non-product outputs of the process that is the focus of the pollution prevention plan. Often uses some form of material flow or input/output analysis. Step 2 of the six pollution prevention steps described in this handbook. Handbook and all appendices.

By-product, an incidental or secondary product made in the manufacture of something else. Appendix B.

By-product recovery, the reclamation of incidental or secondary products from the manufacturing process for reuse or recycling. (See also *on-site reuse and recycling.*) Appendix E and I.

CEPA-toxic substances, substances on Schedule 1 (List of Toxic Substances) of the *Canadian Environmental Protection Act.* Appendix B.

Concentration techniques, mechanical means used to increase the strength of substances and compounds, including wastes, usually through the removal of a component of the waste such as water to increase the recoverability of specific wastes. Example methods include gravity and vacuum filtration, reverse osmosis, freeze vaporization, filter press, heat drying and compaction. Appendix I.

Contingent costs, costs that may or may not be incurred at some point in the future, such as fines for future regulatory infractions, compensation for future environmental damage and costs associated with future lost days due to production-related employee absence. Appendices A and C.

Design for environment (DfE), methods for preventing pollution (and enhancing resource and energy efficiencies) through the design of new products and the reformulation of existing ones. Handbook and Appendix D.

Direct costs, costs that are directly associated with the use and release of each substance, when estimating the full costs of environmental losses from the production process (e.g., raw material inputs, labour). Appendices B and C.

EcoLogo^{M}, a symbol used to indicate a product has met the guidelines of the Environmental Choice Program. (See also *Environmental Choice Program.*) Appendix H.

Environmental Choice Program, Canada's environmental labelling program (for more information, see www.environmentalchoice.com). Appendix H.

Environmental management system (EMS), the part of the overall management system that includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy. Handbook.

Environmentally preferable purchasing, the integration of environmental considerations into purchasing practice. Handbook and Appendix H.

Environmentally responsible inventory management, the incorporation of environmental considerations into inventory management systems. Handbook and Appendix H.

Equipment modifications and process changes, new or alternative technologies or approaches to existing operating systems, processes and practices that result in an overall reduction in the generation of pollution. Handbook and Appendix E.

Feedstock substitution, the use of an alternative feedstock to produce a substance. Appendix F.

Financial analysis, a detailed examination of the financial elements of a manufacturing process to give a complete and accurate picture of the costs of the current process, done as one of the steps in the evaluation and selection of pollution prevention options. Appendices B and C.

Green or environmental specifications, a detailed description of product attributes with environmental significance, including, for example, product or packaging content, labelling, design features, reusability of the product and take-back of off-spec or spent product. Appendix H.

Hazardous material, matter, elements or constituent parts that pose a risk or danger to human health and the environment. Appendices D, E, F, G and H.

Hazardous waste, waste that is hazardous material. Appendices E, F, G and I.

Indirect costs, costs that are associated indirectly with the use and release of a substance, when estimating the full costs of environmental losses from the production process. Such costs may be up-front costs (e.g., siting, design), operating costs (e.g., regulatory, monitoring, compliance or disposal costs including those resulting from poor production quality) or back-end costs (e.g., decommissioning, site clean-up). Appendices A and C.

Inputs, all materials, energy, services and labour entering a system or unit process across the system or unit boundary. Appendix B.

Inventory management system, a set of procedures and devices functioning together to organize and regulate the goods in stock. Appendix H.

ISO 14001, the International Organization for Standardization's standard on environmental management systems. The ISO 14000 series is a family of environmental management standards developed by the International Organization for Standardization (ISO). The ISO 14000 standards are designed to provide an internationally recognized framework for environmental management, measurement, evaluation and auditing. They do not prescribe environmental performance targets, but instead provide organizations with the tools to assess and control the environmental impact of their activities, products or services. The standards address the following subjects: environmental management systems; environmental auditing; environmental labels and declarations; environmental performance evaluation; and life cycle assessment. Handbook and Appendix H.

Less tangible costs, costs that require some subjective interpretation to assess and quantify. They include a range of strategic considerations and are realized as changes in revenues (through market share) or underlying costs. The most common costs in this category include costs arising from changes in corporate image, customer relations, employee morale, and government or regulator relations. Appendix C.

Life cycle assessment (LCA), a specific method for systematically identifying, quantifying and assessing inputs and outputs (i.e., sources of environmental impact) throughout a product's life cycle. It is one of a range of tools that support life cycle management, but is not a prerequisite for life cycle management (Environment Canada – *Environmental Life Cycle Management: A Guide to Better Business Decisions*). Appendix F.

Life cycle management (LCM), a process of minimizing environmental burdens throughout the life cycle of a product or service. The life cycle includes all activities that go into making, using and disposing of a product (Environment Canada – *Environment Life Cycle Management: A Guide to Better Business Decisions*). Appendices D and F.

Life cycle of a product, the steps in the life of a product from raw material acquisition and processing, through its manufacture, use, reuse and maintenance, to its final disposal or recycling. Handbook, Appendices D and H.

Managing materials demand, a process of organizing and regulating a company's material requirements that provides a holistic understanding of those requirements. Appendix H.

Material flow diagram, a graphic representation of the movement of materials used in a process; an aid to clarifying the precise source, quantities or causes of losses, for each unit process. Appendices A and B.

Material(s) mass balance, a comparison of the inputs to and outputs from a process, usually written in equation form as "Mass/volume of inputs = Mass/volume of (outputs + non-product outputs)." Appendices A and B.

Material safety data sheets (MSDS), pamphlets that provide detailed information about the physical properties, toxicity, personnel protection required and other safety precautions and waste disposal needs for specific materials. Contact the manufacturer of the material to obtain an MSDS. Appendices F and H.

Materials accounting, the keeping and verifying of records or statements of materials used in a process to provide a means of finding a general balance between the inputs and outputs of each separate substance. Appendix B.

Materials and feedstock substitution (sometimes referred to as source elimination), the replacement of polluting materials used in the production process, or embedded within a product, with non-polluting or less polluting materials and feedstock. Handbook and Appendix F.

National Pollutant Release Inventory, a nationwide, publicly accessible inventory that provides information on pollutants released to the environment or transferred for disposal in Canada. Covers certain polluting substances as specified by the federal government (for more information, see www.ec.gc.ca/pdb/npri). Appendix B.

Non-product output, or loss, output from a manufacturing process in the form of by-products, solid wastes, liquid wastes, gaseous emissions and wastewater effluents that leave the process prior to treatment. Appendix B.

On-site reuse and recycling, the processes of reusing and recycling at the same place where an activity has been conducted (as opposed to off-site). (See also *recycling* and *reuse*.) Handbook and Appendix I.

Operating efficiencies and training, pollution prevention practices that focus on the introduction of improvements in work procedures and employee training, including changing production schedules to minimize equipment and feedstock changeovers; improving maintenance scheduling; segregating wastes at source; training and encouraging staff to improve material handling and to recognize pollution prevention opportunities; and implementing good housekeeping practices. Handbook and Appendix G.

Outputs, all materials, energy, services and labour leaving a system or unit process across the system or unit boundary. Outputs come in two forms: *finished products or services* that represent the desired output from a system, and *losses* or "*non-product*" *outputs*, in the form of by-products, solid wastes, liquid wastes, gaseous emissions and wastewater effluents. (See also *non-product output, or loss.*) Appendix B.

Pollution control, the addition of processes, practices, materials, products or energy to waste streams to reduce the risk posed by pollutants and waste before their release to the environment. Handbook.

Pollution prevention, the use of processes, practices, materials, products, substances or energy that avoid or minimize the creation of pollutants and waste, and reduce the overall risk to human health or the environment (Government of Canada – *Canadian Environmental Protection Act, 1999*). Handbook and all appendices.

Pollution prevention opportunities, opportunities, for example, to improve environmental and/or economic performance resulting from the identification of the use of toxic substances, the creation of non-product outputs, continuous or episodic losses of material or energy or any other environmental concern. Handbook and Appendix A.

Process control, the manner in which a production system's reliability and performance are ensured. Process control is crucial to operating efficiency. Appendix G.

Process flow diagram, a graphic representation of the series of stages in the manufacturing process. Handbook and Appendices B and C.

Product design and reformulation, methods for preventing the pollution associated with the production, use and disposal of products through the design of new products and the reformulation of old ones. (See also *design for environment.*) Handbook and Appendix D.

Product substitution, the replacement of a product with a less polluting one, such as replacing petroleum-based plastics with starch-based materials. Appendix F.

Purchasing techniques and inventory management, the way in which goods and services are bought, and the practice of controlling the services needed and goods in stock. It includes two distinct practices. ***Environmentally preferable purchasing*** involves the integration of environmental considerations into existing and new purchasing practices. ***Environmentally responsible inventory management*** entails the incorporation of environmental considerations into inventory management systems. Examples of these techniques include just-in-time delivery; avoidance of unnecessary waste generation by ensuring that materials do not stay in inventory beyond their shelf life; quality control for feedstocks to prevent production of "off-spec" products; and use of a clearinghouse to exchange materials that would otherwise be discarded. Handbook and Appendix H.

Recycling, the extension of the effective life span of renewable and non-renewable resources through changes to processes or practices and the addition of energy inputs. Handbook and Appendix I.

Reformulation, a change or difference in the constituents of a product or service and their relative proportions. For achieving pollution prevention, it can be a less disruptive alternative than substitution. Appendix D.

Remanufacture, the restoration of used products or components to a condition with performance characteristics approximating a new product. Appendix D.

Remediation, the use of processes, practices, materials, products or energy to restore to a healthy state ecosystems that have been damaged by human activity. Handbook.

Responsible Care®, a program implemented since 1985 by the Canadian Chemical Producers' Association (CCPA). It requires CCPA member companies to continuously improve "all aspects of the chemical industry's environmental, health and safety performance" and to ensure "openness in communication about its activities and its achievements." Appendix H.

Reuse, the re-employment of products or materials, in their original form or in new applications, with refurbishing to original or new specifications as required. Handbook and Appendix I.

Root cause, often a combination of the materials, machines, methods and policies or regulations that lead to the production of waste. A root cause is realized by tracing the waste or pollutant in question back to its original source. Handbook.

Separation of wastes, the isolation of specific components or by-products with little or no use from process streams. Appendix I.

Source reduction, the elimination or reduction of the production of wastes or pollutants at the point where they originate. Handbook.

Total cost accounting (TCA), a financial tool used to provide a more complete assessment of the true profitability of business investments and operations. Appendix C.

Unit process, a discrete activity (production, processing or servicing action) that has distinct energy, labour and material inputs and outputs and can be considered separately for the purposes of inventory and analysis. Appendix B.

A MODEL POLLUTION PREVENTION PLAN

Appendix A: A Model Pollution Prevention Plan

Purpose

This model pollution prevention (P2) plan is one of a series of documents that form part of the *Pollution Prevention Planning Handbook*. The handbook[1] describes methods that may be used to prepare a pollution prevention plan consistent with this model plan. **It is an important companion document to this model plan**.

This model pollution prevention plan provides an example of the types of information included in an effective pollution prevention plan. It has been structured to help interested persons develop and document an effective plan.

This model plan does not represent the only method for preparing and documenting a pollution prevention plan, and is intended for illustrative purposes only. The advice presented here represents generic advice on "best practices." While pollution prevention can provide significant benefits to organizations regardless of their size and nature of operations, the precise sequence, level of effort, scope of analysis and options reviewed will vary from facility to facility. Each organization should therefore adapt the advice to its own circumstances and, where appropriate, seek advice from other companies that have implemented pollution prevention, from one of the many Internet-based resources supporting pollution prevention, from government officials or from qualified consultants.

Note on Completing this Plan

While this plan presents material in a logical order, the sequence of the sections does not necessarily represent the order in which work will be performed during the planning process. For example, objectives and targets will likely only be set following collection and analysis of baseline data.

Also note that this template suggests measurements on an annual basis and in metric units of mass and volume. It is expected that organizations referring to this template will adopt the units that make the most sense for their operations.

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[1] Available on the CEPA Registry at www.ec.gc.ca/CEPARegistry/plans/p2. To obtain copies, refer to the inside front cover of this document.

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   - 5.2. Inventory of pollution prevention opportunities (materials, substances and other concerns) covered by the plan
   - 5.3. Material flow and materials mass balance
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9. **Review and Evaluation**
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   - 9.2. Record of corrective actions taken
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1.0 Facility Information

Company name:
Name of facility:
Address of facility:
Contact person (accountable manager):
Telephone number: Fax number:
E-mail:
Primary NAICS code:
NPRI ID (if applicable):
Section 56 Notice (if applicable): Date of Notice: Reference No.:
Head Office:
Address:
Contact person:
Telephone number:

2.0 Statement of CEO

(Environmental Policy, Commitment and Endorsement)

Signature of CEO:

3.0 Corporate or Facility Environmental Policy, Principles and Commitments

4.0 Scope and Objectives of the Pollution Prevention Plan

4.1 Scope of the Pollution Prevention Plan

4.1.1 Activities Covered

Indicate whether the plan covers more than one facility, an entire facility, or discrete processes within one or more facilities: ____________

4.1.2 Pollution Prevention Opportunities (Materials, Substances and Other Concerns) Covered

Table 4.1.2: Materials, Substances and Other Concerns Covered by the Pollution Prevention Plan

Pollution Prevention Opportunities (Materials, Substances and Other Concerns) Covered by Plan	Source/Nature of Generation or Use (manufacture, process or otherwise use)[1]	Concerns about the Selected Materials, Substances, Energy Losses, etc.[2]

[1] *Manufacture the material/substance*: produce, prepare or compound, including as a by-product of a production process.
Process the material/substance:
- preparation of the substance, after its manufacture, for distribution in commerce either on its own or as part of a product, or
- use of the substance as part of a chemical or physical process.

Otherwise use the material/substance: as a physical or chemical processing aid, as a manufacturing aid, as a by-product or for an ancillary or other use.

[2] Include, where applicable, "factors to be considered" specified in the section 56 Notice under CEPA 1999.

4.2 Timing

4.2.1 Date plan was prepared _______

4.2.2 Date by which plan will be fully implemented __________

4.2.3 Projected evaluation dates: _________ **and** ________ **and …**

4.3 Overall Objectives of the Pollution Prevention Plan

(include environmental, financial, image, etc., as appropriate)

____

____

____

____

4.4 Pollution Prevention Targets

Table 4.4: Pollution Prevention Targets

Pollution Prevention Opportunities Addressed by Plan	Reduction Target	Estimated Achievement Date	Performance Indicator (to be used to measure progress toward the reduction target)

Notes: Final targets will likely be set following the identification, evaluation, ranking and selection of P2 options.

It can be very difficult to develop a single performance indicator that captures all of the relevant information. In many cases, it is advisable to develop a set of indicators addressing such factors as the absolute quantity of pollutants and waste avoided or prevented; the quantity avoided or prevented as a percentage of throughput; costs; savings and pay-back periods. Indicators such as the number of public complaints received can also be useful in some cases.

5.0 Baseline Review

Note: Section II, "How to Prepare a Pollution Prevention Plan," and Appendix B, "Key Elements of a Baseline Review," provide advice and information on how to develop the information required to complete this part of the model plan.

5.1 Process Flow Diagram

Insert or attach process flow diagram(s).

Note: Appendix B, "Key Elements of a Baseline Review," provides advice about preparing a process flow diagram.

5.2 Inventory of Pollution Prevention Opportunities (Materials, Substances and Other Concerns) Covered by the Plan

5.2.1 Inputs

Table 5.2.1: Inventory of inputs

Input	Quantity Stored On-site	Annual Quantity Used	Quantity Used per Unit of Production	Annual Cost of Input	Cost of Input per Unit of Production

5.2.2 Products

Table 5.2.2: Inventory of Materials/Substances Covered by the Plan That Are Contained in Products

Material/ Substance Covered by Plan	Product(s) Containing the Material/ Substance	Quantity of Material/ Substance Contained per Unit of Product	Annual Production of the Product	Annual Quantity of Material/ Substance Contained in Product	Annual Revenue for the Product

5.2.3 Non-Product Outputs (On-Site Releases and Off-Site Transfers)

5.2.3.1 Inventory of Non-Product Outputs (On-Site Releases and Off-Site Transfers)

Table 5.2.3.1: Inventory of Non-Product Outputs (On-Site Releases Prior to Treatment and Off-Site Transfers

Process Stage[1]	Material/ Substance	Description of Non-Product Output	Type of Release/Transfer[2]	Quantity or Volume
Process Stage A	Material X			
	Material Y			
	Etc.			
Process Stage B	Material X			
	Material Y			
	Etc.			
Etc.	Material X			
	Material Y			
	Etc.			

[1] Process stages to consider include, for example, holding tanks, filling lines, warehouse, shipping, etc.

[2] This includes on-site releases and off-site transfers. "On-site" means within facility boundaries, including on-site landfills, land treatment and farming, spills and leaks. On-site releases are substances released to the air, surface water or land, or injected on-site (underground injection). Off-site transfers include transfers for distribution, recycling and disposal.

5.2.3.2 Analysis of Non-Product Outputs (On-Site Releases and Off-Site Transfers)

Table 5.2.3.2: Analysis of Non-Product Outputs (On-Site Releases and Off-Site Transfers)

Material/ Substance	Process Stage at Which Release or Transfer Occurs (from Table 5.2.3.1)	Description of Non-Product Output (from Table 5.2.3.1)	Type of Release or Transfer (from Table 5.2.3.1)	Quantity or Volume (fromTable 5.2.3.1)	Reason for Release or Transfer	Total Non-Product Outputs of Each Material/Substance (on-site releases + off-site transfers)
Material X						
Material Y						
Etc.						

5.3 Material Flow and Materials Mass Balance

5.3.1 Material Flow Diagram

Insert or attach a material flow diagram.

Note: Appendix B, "Key Elements of a Baseline Review," contains information on how to prepare a material flow diagram.

5.3.2 Materials Mass Balance

Table 5.3.2: Materials Mass Balance

Material/ Substance	Inputs (from Table 5.2.1)	Outputs (pollutants contained in products sent off-site from Table 5.2.2)	Non-Products Outputs (on-site releases + off-site transfers from Table 5.2.3.2)	Mass Balance [1]

[1] Mass balance = Inputs – (Outputs + Non-Product Outputs).

Note: If each mass balance calculation does not equal zero, an output may have been overlooked. Appendix B describes additional analytical tools that can be used to help pinpoint the source and nature of such outputs.

5.4 Summary of Costs Currently Incurred

Notes:
- Complete a cost summary table for each material/substance.
- Appendix C, "Assessing the Costs and Benefits of Pollution Prevention Options," provides information on costs to look for, possible sources of cost information and analytical tools to use in estimating costs.

Table 5.4: Cost Summary Tables (for each material/substance)

Cost Summary for: (material/substance)

Cost Categories (see Table C2 in Appendix C)	Costs Related to Use/Emission of Material/Substance in Producing Product A		Costs Related to Use/Emission of Material/Substance in Producing Product B		Costs Related to Use/Emission of Material/Substance in Producing Product C	
	Annual Qty. (from Table 5.2.1)		Annual Qty. (from Table 5.2.1)		Annual Qty. (from Table 5.2.1)	
	Cost Descriptor	Annual Cost $	Cost Descriptor	Annual Cost $	Cost Descriptor	Annual Cost $
Direct						
Indirect						
Contingent						
Intangible/Less Quantifiable						
Total Costs		$		$		$
Total Cost for Material/Substances:		$	**Total Annual Qty.:**			

5.5 Inventory of Information Gaps

List all items in Section 5 for which information is not available to complete the baseline review.

6.0 Identification and Evaluation of Pollution Prevention Options

Notes: Options should be identified to address both pollution prevention opportunities and information gaps with respect to:

- inputs;
- products; and
- non-product outputs.

Different pollution prevention options may be required to address different types of issues. For example, issues related to products are generally addressed either through product redesign or through some form of a product take-back program to minimize the impact of the pollutant once the product has been discarded.

Appendices D to I describe the following options:
Appendix D: Product Design and Reformulation
Appendix E: Equipment Modifications and Process Changes
Appendix F: Materials and Feedstock Substitution (Source Elimination)
Appendix G: Operating Efficiencies and Training
Appendix H: Purchasing Techniques and Inventory Management
Appendix I: On-Site Reuse and Recycling

Section II, "How to Prepare a Pollution Prevention Plan," describes relevant considerations when identifying, evaluating and selecting options.

6.1 Identification of Options

Table 6.1: Identification of Options

Issues to Be Addressed	Pollution Prevention Option	Predicted Results
Include: • Distributions of the materials/substances in a product, identified in Table 5.2.2 • On-site releases and off-site transfers, identified in Table 5.2.3.2		

6.2 *Evaluation of Options*

6.2.1 Financial Impacts

Table 6.2.1: Costs of Each Pollution Prevention Option

Pollution Prevention Option	One-Time Implementation Costs	Continuing Costs Related to Production/Service Delivery								
		Direct Costs		Indirect Costs		Contingent Costs		Less Tangible or Quantifiable Costs		Total Outgoing Costs $
		Cost Category	Annual Cost $	Cost Category	Annual Cost $	Cost Category	Annual Cost $	Cost Category	Annual Cost $	
A										
B										
C										

Table 6.2.2: Potential Cost Savings from Each Pollution Prevention Option

Pollution Prevention Option	Possible Cost Savings (relative to status quo costs estimated in Table 5.4) $	Notes
A		
B		
C		

Table 6.2.3: Summary of Options Evaluation

Pollution Prevention Option	Technical Feasibility	Environmental Impacts		Financial Impacts			
		Predicted Results (from Table 6.1)	Other Environmental Impacts	One-Time Implementation Costs (from Table 6.2.1)	Ongoing Costs (from Table 6.2.1)	Potential Savings (from Table 6.2.1)	Internal Rate of Return
A							
B							
C							

6.3 Business Considerations

Identify any strategic considerations that would affect the evaluation of specific pollution prevention options (i.e., render certain evaluation criteria more important than others or elevate the priority of a specific option).

6.4 Selection and Ranking of Pollution Prevention Options

Table 6.4: Summary Ranking of Pollution Prevention Options

Pollution Prevention Option	Comments
Highest-ranking option	
...	
...	
...	
Lowest-ranking option	

7.0 Implementation Plan

Table 7.0: Implementation Schedule

Selected Option (from Table 6.4)	Action Required	Resources Required	Responsible Party	Predicted Reduction	Planned Completion Date	Predicted Results as % of Overall Target

8.0 Monitoring and Reporting

8.1 Monitoring Program and Data

8.1.1 Monitoring Program

Responsible Person: ____________________

Describe how your organization will monitor:

- implementation of the pollution prevention actions; and
- progress toward achieving objectives and targets.

Identify roles and responsibilities, monitoring mechanisms, and frequency.

8.1.2 Monitoring Implementation and Performance

Note: Complete this section on an ongoing basis during the implementation of the plan.

Table 8.1.2: Monitoring Implementation and Performance

Reporting Period	Action Item to Be Implemented During Reporting Period	Implementation Status	Reductions in Use, Releases and Transfers		% Achievement of Target	Reasons for Deviation from Predicted Reductions
			Predicted Reductions (from Table 7.0)	Actual Reductions		

8.2 Reporting Program and Data

Note: Complete this section on an ongoing basis during the implementation of the plan.

8.2.1 Reporting Plan

Describe how results and changes will be reported internally and externally.

8.2.2 Reporting Data

Table 8.2.2: Reporting on Implementation of Pollution Prevention Plan and Performance

Material/ Substance	Changes in			Pollution Prevention Option Implemented	Costs or Savings	Target Result and Date	% Achievement of Target	Deviation from Implementation Plan	Reasons for Deviation
	Inputs	Product	Non-Product Outputs (losses)						

9.0 Review and Evaluation

9.1 Review and Evaluation Plan

Responsible Person:

Describe the review and evaluation process. Identify responsibilities for collecting and presenting the required information to the reviewers, responsibilities for conducting the review, and frequency of the review.

9.2 Record of Corrective Actions Taken

Note: Complete this section on an ongoing basis during the implementation of the plan.

Table 9.2: Corrective Actions Taken

Deficiencies Identified (from Table 8.1.2)	Corrective Action	Responsibility	Deadline

9.3 Record of Target Revisions Made

Note: Complete this section on an ongoing basis during the implementation of the plan.

Table 9.3: Revisions to Targets

Material/Substance	Previous Target	Revised Target	Reason for Change

ANALYTICAL TECHNIQUES FOR PREPARING A POLLUTION PREVENTION PLAN

Appendix B: Key Elements of a Baseline Review

Introduction

Pollution prevention is "the use of processes, practices, materials, products, substances or energy that avoid or minimize the creation of pollutants and waste, and reduce the overall risk to the environment and human health" (*Canadian Environmental Protection Act, 1999*). Pollution prevention is at the top of a hierarchy of environmental protection methods that also include off-site reuse and recycling, pollution control or treatment, disposal/destruction, remediation and clean-up. While all environmental protection methods provide some benefits, pollution prevention can provide the most cost-effective opportunities for reducing environmental and health risk while improving a business's bottom line.

Pollution prevention planning is a systematic, comprehensive method of identifying options to minimize or avoid the creation of pollutants or waste. There are six main steps to developing and implementing a pollution prevention plan:[1]

- commitment and policy;
- baseline review;
- planning;
- implementation;
- monitoring and reporting; and
- evaluation, review and improvement.

The second step of the planning process, the baseline review, provides the detailed information required to identify an organization's most significant sources of pollution and to develop solutions for them. It is a systematic approach to building the in-depth knowledge of production and/or product life cycle processes necessary to identify pollution prevention opportunities.

This information sheet describes some of the main analytical techniques that are useful in completing the baseline review:

- process flow diagrams;
- material flow diagrams;
- input/output inventories;
- materials accounting; and
- materials mass balances.

It also provides examples to illustrate the use of some of these techniques.

Defining the Systems Boundary

The first step in a baseline review should be to define the system boundary within which the plan will focus. Will it consider a specific functional area or process, and will it be circumscribed to within the "plant gates" or also include off-site disposal impacts, suppliers and product impacts? This decision is important, as it will influence the subsequent identification of pollution prevention options. For example, if the greatest environmental impact of a product comes at its end-of-life stage, but the system boundary contains only the manufacturing stage, the plan will be unlikely to identify product design and reformulation as a pollution prevention option.

In choosing the system boundary, consideration should be given to which stages in the life cycle of the product, process or service cause the greatest environmental impacts (extraction or processing of raw materials and inputs, product manufacturing, product use, or end of life). Figure B1 illustrates potential environmental impacts throughout a typical product life cycle.

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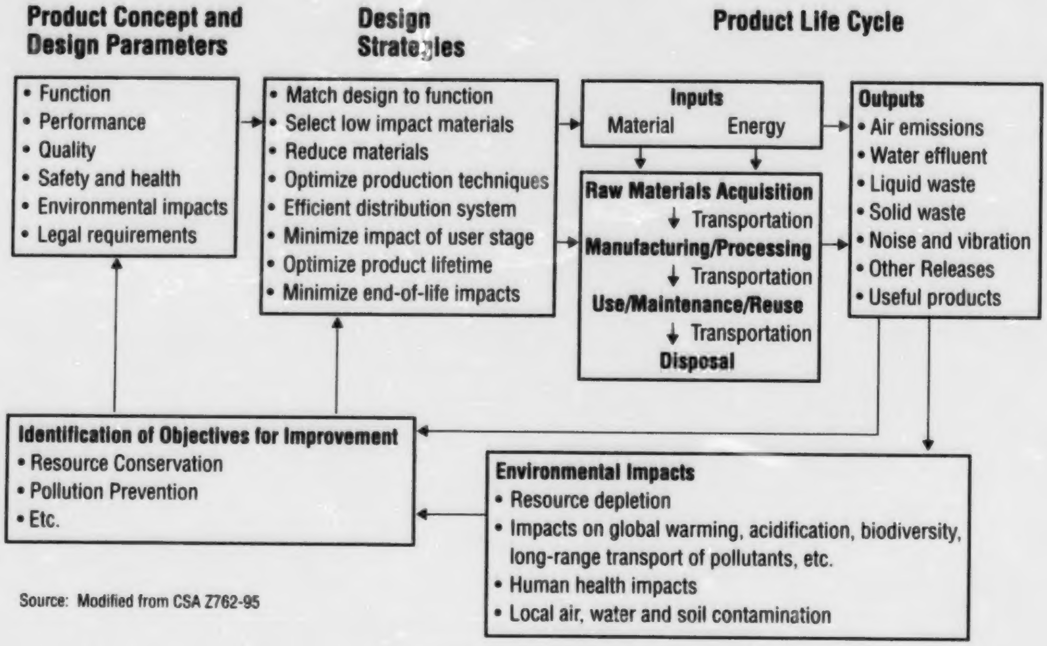
[1] For further information on these steps, see the section "How to Prepare a Pollution Prevention Plan."

Figure B1: Conceptual Model of a Product's Life Cycle Impacts


Product Concept and Design Parameters
Design Strategies
Product Life Cycle
• Function
• Performance
• Quality
• Safety and health
• Environmental impacts
• Legal requirements
• Match design to function
• Select low impact materials
• Reduce materials
• Optimize production techniques
• Efficient distribution system
• Minimize impact of user stage
• Optimize product lifetime
• Minimize end-of-life impacts
Inputs
Material
Energy
Raw Materials Acquisition
Transportation
Manufacturing/Processing
Transportation
Use/Maintenance/Reuse
Transportation
Disposal
Outputs
• Air emissions
• Water effluent
• Liquid waste
• Solid waste
• Noise and vibration
• Other Releases
• Useful products
Identification of Objectives for Improvement
• Resource Conservation
• Pollution Prevention
• Etc.
Environmental Impacts
• Resource depletion
• Impacts on global warming, acidification, biodiversity, long-range transport of pollutants, etc.
• Human health impacts
• Local air, water and soil contamination

Source: Modified from CSA Z762-95

Basic Process Flow Diagrams

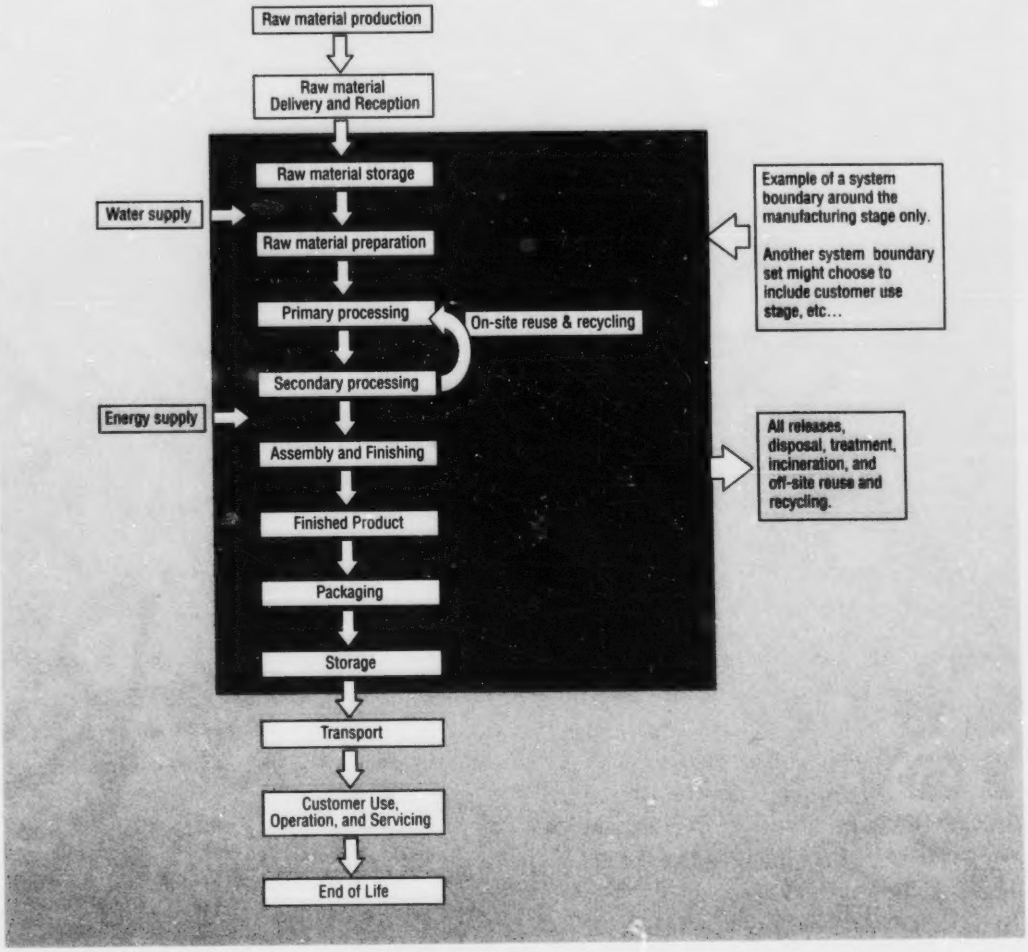
Facility plans and process diagrams are a good starting point for developing the process flow diagram, although most facilities have experienced retrofits, expansions and repairs that are not reflected in design or construction drawings. Ideally, the process flow diagram should identify each discrete step (unit process) in the production activity. This provides a "bird's eye view" of the relevant processes.
A unit process is a discrete activity (production, processing or servicing action) that has distinct energy, labour and material inputs and outputs. Break activities into separate unit processes when there may be an important environmental impact that could get lost or be difficult to isolate and quantify if left within a larger unit process grouping. Identify whether a unit process is a periodic, batch or continuous process. This will help identify specific options for pollution prevention.

If focusing on one or more specific substances (e.g., specific CEPA-toxic substances targeted for pollution prevention planning), identify the unit processes associated with each use of that substance, and the function of the use (degreasing, solvent, etc.).

When mapping the process flow diagram, include on-site reuse and recycling unit processes, but exclude all pollution control or treatment processes, and all off-site reuse and recycling. The reason for doing this is to identify the material, energy and water losses that leave the process prior to treatment, without assuming that wastes are already being dealt with in the most effective manner possible.

Figure B2 illustrates a generic process flow diagram for a typical production process.

Figure B2: Generic Manufacturing Process Flow Diagram


Raw material production
Raw material Delivery and Reception
Raw material storage
Water supply
Raw material preparation
Primary processing
On-site reuse & recycling
Secondary processing
Energy supply
Assembly and Finishing
Finished Product
Packaging
Storage
Transport
Customer Use, Operation, and Servicing
End of Life

Example of a system boundary around the manufacturing stage only.

Another system boundary set might choose to include customer use stage, etc...

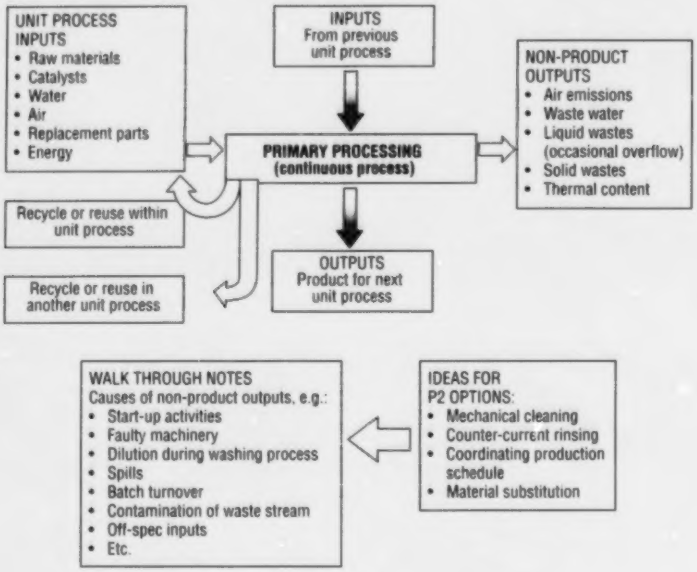
All releases, disposal, treatment, incineration, and off-site reuse and recycling.

Material Flow Diagrams

Material flow diagrams such as Figure B3 help clarify the precise source, quantities or causes of losses for each unit process. They map inputs and outputs for each unit process onto the process flow diagram developed above. They also serve as an initial, qualitative identification of obvious sources of losses.

A facility **walk-through** by the pollution prevention team is a good way to initiate the development of a material flow diagram. It is not unusual to identify processes, activities or machinery that deviate from the official facility drawings and process diagrams. A walk-through is usually the only way to identify fugitive sources of losses or unusual sources of losses (such as breakdowns), as these are not planned and therefore do not show up on process flow diagrams. These should be noted and the process flow diagrams revised. In addition, it may be of value to speak to shop floor staff, as they can provide valuable input and clarification regarding specific processes as well as any relevant non-documented manners for which they conduct housekeeping and maintenance that may affect the process.

Figure B3: Generic Material Flow Diagram for Primary Processing Stage


UNIT PROCESS INPUTS
• Raw materials
• Catalysts
• Water
• Air
• Replacement parts
• Energy
INPUTS From previous unit process
NON-PRODUCT OUTPUTS
• Air emissions
• Waste water
• Liquid wastes (occasional overflow)
• Solid wastes
• Thermal content
PRIMARY PROCESSING (continuous process)
Recycle or reuse within unit process
Recycle or reuse in another unit process
OUTPUTS Product for next unit process
WALK THROUGH NOTES
Causes of non-product outputs, e.g.:
• Start-up activities
• Faulty machinery
• Dilution during washing process
• Spills
• Batch turnover
• Contamination of waste stream
• Off-spec inputs
• Etc.
IDEAS FOR P2 OPTIONS:
• Mechanical cleaning
• Counter-current rinsing
• Coordinating production schedule
• Material substitution

During the walk-through, it is important to follow each process stage from one end to the other, recording the inputs and outputs for each unit process and gaining an understanding of the daily production, start-up and shutdown, and cleaning processes. More than one walk-through may be necessary in order to observe each of these activities properly.

Remember to:

- identify any on-site reuse or recycling streams;
- include materials that are used only occasionally and/or do not appear in output streams (such as catalysts, coolant oil and cleaning materials); and
- label all discharge streams according to whether they are periodic, intermittent or continuous.

Any quantified data that are readily available should be collected at this stage. If the required data are not available, this step can first be conducted in a qualitative manner in order to identify which unit processes are the source of the greatest environmental impact and/or have the greatest potential for a pollution prevention solution. These unit processes can be quantified and inventoried.

It is important not to get bogged down trying to make a perfect material flow diagram; even a preliminary diagram can help provide insights into sources and quantities of losses.

Input/Output Inventories

In this step, systematic quantification of inputs and outputs are added to the portrait that has already been built through the flow diagrams. These data will serve three functions. They will:

- confirm or improve the planner's understanding of facility operations from a materials flow and materials loss perspective;

- provide a sound way of prioritizing processes for more detailed analysis; and
- establish core data on which to base more detailed analysis, evaluate options and monitor future progress.

The inventory can be developed either for the system as a whole (facility level) or for the specific unit processes identified as the source of the greatest environmental impact. It can also be done for all material flows or for the specific substance targeted for reduction.

A decision to inventory only selected unit processes or selected substances will preclude the ability to develop a more complete understanding of material flows across the system and to complete a facility-wide mass balance, which are both important tools for identifying and quantifying previously unknown losses. On the other hand, an inventory of the system as a whole should be supplemented by a more detailed analysis of selected unit processes.

Inputs are all materials, energy, services and labour entering the system or unit process boundary. Outputs come in two forms: ***finished products or services*** that represent the desired output from a system, and ***losses or "non-product" outputs*** in the form of by-products, solid wastes, liquid wastes, gaseous emissions and wastewater effluents. Loss is what leaves processes prior to treatment. It is important not to confuse this with what is released to the environment after treatment.

Each substance or material covered by the pollution prevention plan should be accounted for as it moves through the system or unit process. This requires selecting appropriate metrics for comparison across the system. Such metrics should be based either on output (such as volume or mass of product) or on unit of time (such as per day or per year). The measurement unit will vary from case to case, but the following guidelines should be considered:

- In determining the time factor, always choose a time span that includes production quantity (e.g., tonne/year or kg/hour).
- Take one full batch in the case of batch production. Include start-up, shutdown and cleaning operations, which are often the source of losses.
- If losses are associated with shutdown, averaging over long periods may be necessary.
- In the case of gases, calculate on the basis of volume at standard conditions.

Cost alone is not a useful unit for comparison, since prices for both inputs and products may fluctuate, leading to large margins of error if quantities are derived from financial data. Nonetheless, it is important to record all costs and revenues associated with inputs and outputs while doing this inventory step, in order to conduct the financial analysis of pollution prevention options. Tips on costs to consider in order to complete a comprehensive financial analysis are found in Appendix C, "Assessing the Costs and Benefits of Pollution Prevention Options."

Inventory of Inputs

Inventory all the inputs entering the system or unit process. If the pollution prevention plan is focused on a specific substance, inventory inputs not only of that substance, but of any material that may act as a medium for transfer of the substance (such as water or contaminated waste streams).

In developing the input inventory, it will be important to establish a time frame for the inventory (daily, weekly, monthly, annually, etc.). One important factor in doing so will be whether there are significant fluctuations in inputs and whether the flow is batch or continuous.

Data sources for inputs at the facility or system level can usually be found in records maintained by the company. These include bills of lading and purchase, stock and inventory management, financial management, compliance, and reporting records. Some inputs (such as water, some energy inputs and other materials) may be directly measured with meters.

If large on-site inventories are kept, be sure to reconcile between purchased and actual consumption. If financial management records are being used as the data source, be sure to collect actual volume as well as financial data. It is useful to collect financial data on the cost for each input at this stage for use in the subsequent financial analysis step.

Inventory of Product Output and Quantities of Substance(s) Contained Therein

Inventory the volume or mass of each final product leaving the system boundary. Again, data for this can usually be found in sales records or other internal management records.

Document the annual revenue for each final product for use in the subsequent financial analysis step.

If the pollution prevention plan is focused on a substance, inventory the volume or mass of the substance contained in the product, if known. This may require engineering calculations or estimates. If this is not known, it can be determined through the materials accounting or materials mass balance step described below.

Inventory of Non-Product Outputs

Non-product outputs (or losses) will be the most difficult part of the inventory to complete, as most companies do not routinely measure losses in a comprehensive fashion.

Inventory all known losses from the system boundary. Losses may occur through air emissions; wastewater effluent; liquid wastes for underground injection and off-site disposal and recycling; and solid wastes for on-site release to land, or off-site disposal and recycling.

Also inventory the non-product outputs that are reused or recycled in-process or on-site. Materials for recycling contain lost investments of embodied energy and labour that should be minimized.

Data sources for non-product outputs or losses include waybills for solid and liquid waste transfers; compliance data; release and inventory reporting records; direct measurements or sampling results for air emissions and water effluent; monitoring; and engineering calculations or estimates. Some companies report under the National Pollutant Release Inventory, and can start with these measurements.

The precision of analytical data and flow measurements is important. With poor measurement techniques, the absolute error in measurement of these quantities may be greater than the actual waste stream or emission. Accurate calibration and the use of standard measurement methods and procedures are also essential.

Record all known costs associated with each category of non-product output. Costs can include direct costs, such as treatment and disposal costs, and indirect costs such as monitoring and permit fees. Appendix C, "Assessing the Costs and Benefits of Pollution Prevention Options" provides suggestions on how to conduct a total cost assessment.

It may not be possible to identify all sources of non-product outputs at this stage. New sources may be identified and quantified through the materials accounting or materials mass balance approach (see below).

Materials Accounting and Materials Mass Balance

The materials accounting and materials mass balancing steps are important for any pollution prevention program: they make it possible to identify and quantify previously unknown losses.

Materials accounting means finding a general balance between the inputs and outputs of each separate substance. Materials accounting is based on the premise that, for the facility as a whole or for individual unit processes, all materials entering a facility must come out in one form or another.

$$\text{Mass/volume of inputs} = \text{Mass/volume of (output + non-product output)}$$

If this equation generally balances, then the sources of non-product outputs have been identified and an analysis of the cause of the non-product output can be initiated (see below). If the equation is significantly out of balance, then this unaccounted mass or volume represents an unknown output and should be investigated.

If the reason for the discrepancy cannot be found easily, then analysis at the unit process level can be used to ferret out the problem. This can be done by doing a *materials accounting* for each specific unit process, or by doing a *materials mass balance*.

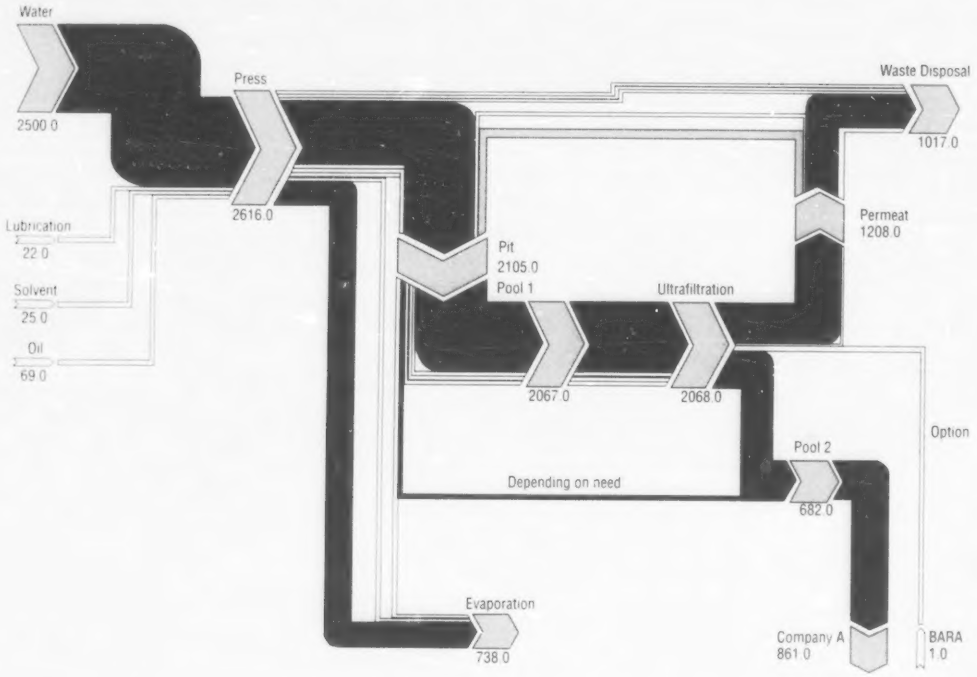
A **materials mass balance** can be used to clear up any problems unsolved through the materials accounting approach. A materials mass balance also offers greater accuracy, but is more time and data consuming than materials accounting. In a materials mass balance, greater efforts are made to balance the statement:

$$\text{Mass in} = \text{Mass out} + \text{Accumulation}$$

The main difference is that in materials mass balance, greater accuracy is achieved by using samples and measurements instead of existing records and estimations. The entire process should ultimately be balanced on a kilogram-for-kilogram basis, rather than accounting for each substance alone as in materials accounting.

Materials accounting and materials mass balances can be presented in a tabular or diagrammatic format. A Sankey diagram provides one useful method for representing a picture of material flows and balances. An example of a Sankey diagram is shown in Figure B4.

Figure B4: Example Sankey Diagram


Water
2500.0
Press
2616.0
Lubrication
22.0
Solvent
25.0
Oil
69.0
Pit
2105.0
Pool 1
2067.0
Ultrafiltration
2068.0
Waste Disposal
1017.0
Permeat
1208.0
Option
Pool 2
682.0
Depending on need
Evaporation
738.0
Company A
861.0
BARA
1.0

Source: JKMAS Inc. distributes Sankey diagrams in North America. Contact JKMAS Inc. at 1630 North Main Street PMB 330, Walnut Creek, CA 94596 USA (925) 516-2121 or visit their website (http://sdraw.com).

Example of Techniques for Conducting a Baseline Review

The following example illustrates some of the tools that can be used to complete a baseline review, including material flow diagrams, input/output inventories and materials mass balances.

Scenario: Use of Substance X

A facility manufactures cleaners for household use. Substance X is used in the production of four different types of cleaners to keep the hydrophobic solvents and emulsifiers in solution. A total of 16,000 250 ml glass bottles are manufactured annually.

"Off spec" product and spillage of the product containing Substance X are stored in 205 litre drums on-site and transferred off-site for disposal.

Example Material Flow Diagram

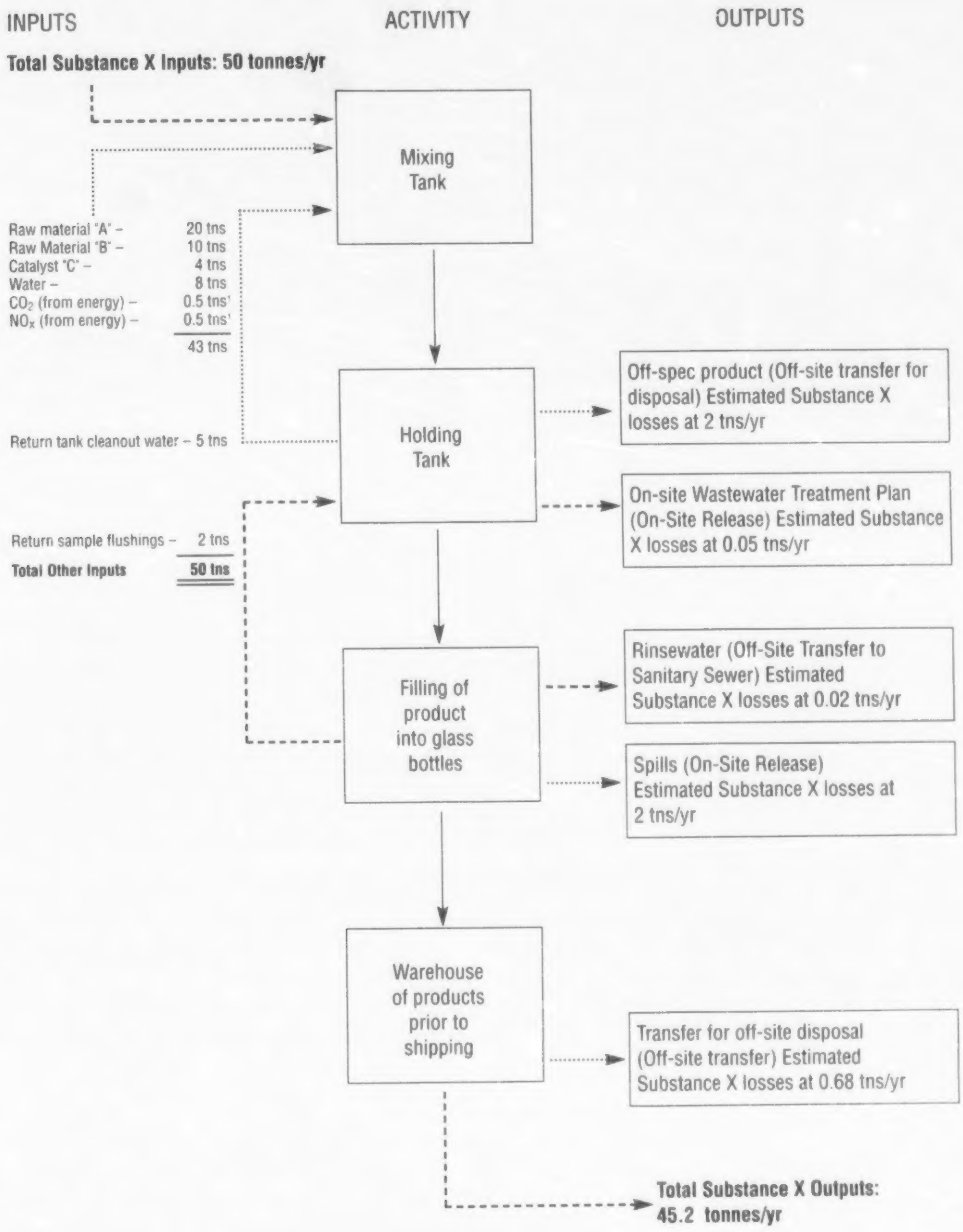
In this example, Substance X will be tracked as it moves through the process stages in a batch manufacturing plant. The material flow diagram in Figure B5 will build a detailed profile of the inputs, outputs and non-product outputs (or losses, including on-site releases and off-site transfers).

Example Input/Output Inventories

The quantification of inputs and outputs, through an inventory, will further build a detailed profile of the production processes and all associated inputs, product outputs and non-product outputs (losses).

In this example, input/output inventories are developed for Substance X at a facility level.

Figure B5: Example Material Flow Diagram


INPUTS
ACTIVITY
OUTPUTS
Total Substance X Inputs: 50 tonnes/yr
Mixing Tank
Raw material "A" – 20 tns
Raw Material "B" – 10 tns
Catalyst "C" – 4 tns
Water – 8 tns
CO_2 (from energy) – 0.5 tns[1]
NO_x (from energy) – 0.5 tns[1]
43 tns
Return tank cleanout water – 5 tns
Holding Tank
Off-spec product (Off-site transfer for disposal) Estimated Substance X losses at 2 tns/yr
On-site Wastewater Treatment Plan (On-Site Release) Estimated Substance X losses at 0.05 tns/yr
Return sample flushings – 2 tns
Total Other Inputs 50 tns
Filling of product into glass bottles
Rinsewater (Off-Site Transfer to Sanitary Sewer) Estimated Substance X losses at 0.02 tns/yr
Spills (On-Site Release) Estimated Substance X losses at 2 tns/yr
Warehouse of products prior to shipping
Transfer for off-site disposal (Off-site transfer) Estimated Substance X losses at 0.68 tns/yr
Total Substance X Outputs: 45.2 tonnes/yr

Legend:

[1] Energy is normally calculated in KJ but has been converted to tonnes of each greenhouse gas based on estimates provided by the National Pollutant Release Inventory (NPRI) reporting process.

- - - - - - -▶ Periodic ··················▶ Intermittent ————▶ Continuous

Table B1: Example Input Inventory

Inputs	Quantity Stored On-Site	Annual Quantity Used (tonnes)	Quantity Used per Unit of Production	Annual Cost of Input $	Cost of Input per Unit of Production $/tonne
Substance X	NA	50	0.0031	15 k	0.93
Raw material "A"	NA	20	0.0012	6 k	0.36
Raw material "B"	NA	10	0.0006	3 k	1.8
Catalyst "C"	NA	4	0.0002	1 k	0.5
Water	NA	8	0.0005	0.8 k	0.05
Energy	NA	20,000 kWh	1.25	2.2 k	0.14/kWh
Return tank cleanout water	NA	5	0.0003	-	-
Return sample flushings	NA	2	0.0001	-	-

Table B1 illustrates an input inventory using the following data:

- 50 tonnes of industrial grade Substance X purchased annually
- production of 16,000 250 ml containers of cleaner.

The inventory of the organization's products containing Substance X yields:

- approximately 45.2 tonnes of Substance X are transferred off-site in the products
- approximately 4.75 tonnes of Substance X are lost during the production process as non-product outputs.

Table B2 shows the Inventory of Substance X losses (non-product outputs).

Table B2: Example Loss (Non-Product Output) Inventory

Process Stage	Description of Substance X Non-Profit Output	Type of Release/ Transfer	Estimated Quantity tonnes/yr	Reason for Release/ Transfers	Total Non-Product Output of Substance X tonnes/yr
Holding tank	Rinsing of tanks and lines	On-site release to surface water (from treatment plant)	0.05	Rinsing of residual intermediate product generates rinsewater with small quantities of Substance X.	4.75
	"Off-spec" product	Off-site transfer for disposal	2	Some batches do not have suitable specifications for sale.	
Filling line	Rinsing of filled bottles	Off-site transfer for disposal (to sanitary sewer)	0.02	Filled bottles are rinsed before packaging in shipping boxes; this generates rinsewater with small quantities of Substance X.	
	Overflow during filling	Off-site release to land	2	Spillage occurs during the filling process.	
Warehouse and shipping	Spillage from broken bottles	Off-site transfer for disposal	0.68	Product falls off pallets and glass bottles break while in transit from storage to shipping.	

Note: This table is based on Table 5.2.3.2 in Appendix A, "A Model Pollution Prevention Plan."

Example Materials Mass Balance

Materials mass balances are useful to organize data, identify gaps and quantify previously unknown losses. They can help quantify substances where quantitative data are limited or where information is difficult to collect. Unaccounted-for losses can be revealed when "mass in" (inputs) fails to equal "mass out" (losses plus outputs). Such an imbalance can also indicate that fugitive emissions or unidentified releases are occurring. In the example illustrated in Table B3, the evaporation of Substance X from the mixing tank can be estimated (0.05 tonnes/year) as the difference between Substance X put into the tank (inputs) and Substance X within products and removed by disposal, treatment and spills (losses plus outputs).

Table B3: Example Materials Mass Balance

Substance	Inputs tonnes	Outputs Substance X contained in products sent off-site	Non-Product Outputs on-site releases + off-site transfers	Mass Balance*
Substance X	50	45.2	4.75	0.05

* Mass Balance = Inputs – (Outputs + Non-Product Outputs)

References and Resources

For more information on pollution prevention and pollution prevention planning:

Canadian Pollution Prevention Information Clearinghouse: www.ec.gc.ca/cppic

Canadian Centre for Pollution Prevention: www.c2p2online.com

Canadian Environmental Protection Act, 1999: www.ec.gc.ca/CEPARegistry

Your Environment Canada Regional Office.

For more information on techniques for conducting a baseline review for pollution prevention planning:

City of Toronto, 1999. *A Guidance Manual for Pollution Prevention Plans*: www.city.toronto.on.ca/involved/wpc/nbylaw.htm

Ayres, R.U., and L.W. Ayres, 1999. *Accounting for Resources 1: Economy-Wide Applications of Mass Balance Principles to Materials and Waste*. U.K.: Edward Elgar Publishing

Ayres, R.U., and L.W. Ayres, 1999. *Volume 2: The Life Cycles of Materials*. U.K.: Edward Elgar Publishing

Freeman, Harry, 1995. *Industrial Pollution Prevention Handbook*. McGraw-Hill.

Industrial Research Assistance Program of the National Research Council of Canada, Design for Environment website: www.nrc.ca/dfe

U.S. Environment Protection Agency's Design for Environment Program website: www.epa.gov/opptintr/dfe

Appendix C: Assessing the Costs and Benefits of Pollution Prevention Options

Introduction

Over the past 30 years, expenditures on environmental protection in all sectors (including pollution control, waste management, monitoring, regulatory reporting, legal fees and insurance) have increased significantly. Pollution prevention approaches aim to avoid or reduce these costs by implementing alternatives that minimize the creation of the pollutants and wastes in the first place.

Pollution prevention is the "use of processes, practices, materials, products, substances or energy that avoid or minimize the creation of pollutants and waste, and reduce the overall risk to the environment or human health" (*Canadian Environmental Protection Act, 1999*). Pollution prevention is at the top of a hierarchy of environmental protection methods that also include off-site reuse and recycling, pollution control or treatment, disposal/destruction, remediation and clean-up. While all environmental protection methods provide some benefits, pollution prevention can provide the most cost-effective opportunities for reducing environmental and health risks while improving a business's bottom line.

Assessing the costs and benefits of existing environmental protection practices and of pollution prevention options is important to ensuring that pollution prevention initiatives result in the most cost-effective outcomes possible. This information sheet describes basic steps and tools for identifying and estimating the quantifiable and less quantifiable costs and benefits associated with the status quo and with options identified during pollution prevention planning.

Strategies for Improving Environmental Performance and the Bottom Line Through Pollution Prevention

The degree to which an enterprise minimizes or avoids environmental risk and maximizes potential environmental opportunities can have important implications for its profitability. Surveys have indicated that some customers are making the environment an important part of their purchasing decisions, and that competitors in some fields are promoting the "greenness" of their products and services in their marketing strategies. Environmental performance is becoming an important factor in some supply chains, such as in automobile manufacturing. Businesses are recognizing that pollution and waste represent inefficiencies and lost profits in their production processes. Attention to environmental opportunities and obligations affects not only a business's cash flow but also the marketability and value of its assets.

As a result of factors like these, an increasing number of companies are recognizing the competitive advantage to be gained in "valuing" environmental performance, as opposed to viewing it as a cost of doing business. One approach[1] to doing this consists of:

- identifying the strategic business value of environmental performance;
- measuring results that matter in financial terms; and
- communicating environmentally linked financial performance.

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[1] This approach is described further in *Uncovering Value: Integrating Environmental and Financial Performance*. Program on Energy, the Environment, and the Economy. The Aspen Institute. Washington, D.C., 1998.

Table C1: Links Between a Company's Environmental Strategies and Investor Interests

	Franchise Protection	Process Changes	Product Changes	New Market Development
Business value	Right to operate	Cost and liability reduction	Market share and pricing power through customer loyalty and reputation	New markets
Financial impact	• Reduces earnings • Reduces risk	• Increases margins • Often uses less capital • Increases return on equity • Reduces risk	Increases competitive advantage	• Increases sales • Increases competitive advantage

Source: Adapted from D. Reed, "Green Shareholder Value, Hype or Hit?" *Sustainable Enterprise Perspectives*, World Resources Institute, 1998

1. **Identifying the strategic business value of environmental performance** requires direct communication between an organization's financial/business side and its technical/environmental side to ensure an in-depth understanding of the relevance of environmental considerations to core business strategies. These linkages can include:

- **protecting the business franchise:** Ford, GM and Daimler-Chrysler require all of their "Tier 1" suppliers to have an environmental management system (EMS) that is certified under ISO 14001. Suppliers without an EMS may lose important customers.
- **changing processes to improve efficiency:** Millar Western developed an effluent-free process for its new pulp mill in Meadow Lake, Saskatchewan. For approximately the same cost as traditional treatment processes, the new mill has eliminated the discharge of liquid effluents into the environment, uses 40% less fresh water than traditional kraft mills and has production yields 60% to 100% greater than traditional kraft mills.
- **developing new products:** Volvo increased its market share in one truck segment by 35% over a three-year period by differentiating its trucks on their environmental features (fuel efficiency and low emissions). This boosted the company's operating income from 30% to 56% during the same time period.
- **building and entering new markets:** Green Mountain Energy Resources, a power marketer in the United States, is able to charge a premium for electricity generated from renewable sources. As a result of consumer preference for "cleaner" power, it has become the largest marketer of residential power across the United States.

Table C1 provides a way of examining how environmental performance can be linked with business strategy to reveal potential bottom-line benefits.

2. **Measuring results that matter in financial terms** involves knowing how the company is currently valued by investors and what measures are used, how the environmental aspects of its strategies affect those measures and how to collect data that are meaningful in demonstrating

Table C1: Links Between a Company's Environmental Strategies and Investor Interests

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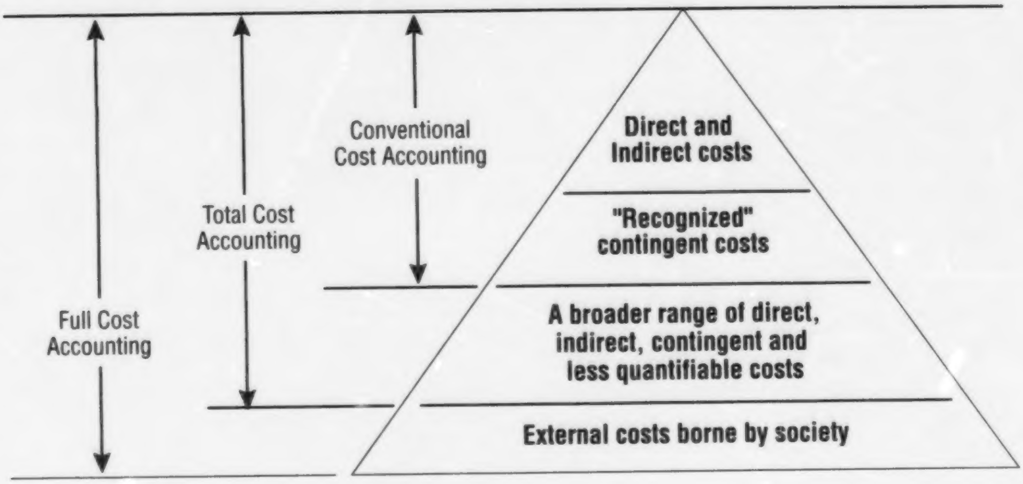
2. **Measuring results that matter in financial terms** involves knowing how the company is currently valued by investors and what measures are used, how the environmental aspects of its strategies affect those measures and how to collect data that are meaningful in demonstrating

Figure C1: Relationships Between Forms of Accounting


Full Cost Accounting
Total Cost Accounting
Conventional Cost Accounting
Direct and Indirect costs
"Recognized" contingent costs
A broader range of direct, indirect, contingent and less quantifiable costs
External costs borne by society

Source: Modified from: *Total Cost Assessment Guidelines*, 1997, B.C. Ministry of Environment, Lands and Parks.

that connection. Many companies pursue environmental strategies that involve process change, leading to cost efficiencies and increased earnings. Accurate and complete information about the costs and savings associated with those changes is essential to sound and fair evaluation of these strategies over time.

3. **Communicating environmentally linked financial performance** requires expressing measurements and results in terms that are understood, relevant to and used by the target audience – whether managers or investors.

Communication of measurement information must be:
- shared and understood internally by all managers (i.e., a common language);
- expressed in terms of business functions and goals as well as being financially relevant; and
- credible, consistent and comparable (over time and between companies).

Tools for Assessing the Profitability of Pollution Prevention Options

Analytical tools that can be used in evaluating pollution prevention options include:
- conventional cost accounting (CCA);
- total cost accounting (TCA);
- full cost accounting (FCA); and
- life cycle assessment (LCA).

In different ways and with varying levels of usefulness, these tools can be used to identify, assess and allocate the environmental costs of each pollution prevention option being considered. These tools represent only a sample of the environmental managerial accounting tools that are being developed and implemented in a number of jurisdictions worldwide and that are available to an enterprise for use in assessing options. Figure C1 demonstrates the relationships between forms of cost accounting.

Conventional cost accounting (CCA) focuses primarily on determining financial costs based on categories of direct and indirect costs associated with a particular activity (product, service, process). Using this form of accounting, many of the environmental costs associated with permitting, insurance premiums, legal fees, utilities costs, etc., are attributed to overhead accounts, which may then be arbitrarily allocated to products, processes or services (e.g., on a square foot or product volume basis) or may not even be allocated at all. As a consequence, managers and executives are often unaware of the extent of these costs and have little or no incentive to reduce them. These costing methods can also distort the real cost picture for products or product lines and result in sub-optimal decisions from both an environmental and a financial perspective.

Total cost accounting (TCA) is a financial tool used to provide a more complete assessment of the true profitability of business investments and operations. It has been used to evaluate alternative capital investments, operational expenditures and procurement decisions. Particularly when used in conjunction with activity-based costing, TCA enhances decision making by improving the underlying cost information on which decisions are based. Relative to conventional cost accounting and project evaluation approaches, TCA:

- takes into account a wider range of direct and indirect costs and savings;
- uses longer time horizons that reflect the full economic or commercial life of the project;
- uses financial indicators that incorporate the time value of money;
- reveals hidden costs, by relating them to the activities that cause them; and
- considers uncertain or less quantifiable costs.

It is important to note that TCA is not a new method of cost accounting but rather an existing tool for thinking about costs and project evaluation in a different, more comprehensive way. In most cases it is the best tool for identifying and assessing the costs of pollution prevention options.

Full cost accounting (FCA) attempts to identify and quantify the external costs associated with the activities of a given enterprise that are currently being borne by society (damage to health, land, buildings, crops, vegetation, water bodies etc.). Companies do not normally include an assessment of external costs in the information collected to assist in choosing among pollution prevention options, partly because they are not currently held legally accountable and liable for most such impacts but mainly because of the difficulty of measuring such costs. Very few companies have the resources and expertise to carry out FCA, and there is no widely accepted methodology for doing so in a practical manner. Nonetheless, with the growing acceptance worldwide of the "polluter pays" principle, companies are becoming alerted to the increasing demand by society to "internalize" these traditionally external costs.

Life cycle assessment (LCA) is a method for systematically identifying, quantifying and assessing inputs and outputs (i.e., sources of environmental impact) throughout a product's life cycle, from raw material acquisition and processing, through its manufacture, use, reuse and maintenance, to its final disposal or recycling. Although LCA is heavily relied on by some large companies, such as Alcan and Volvo, in many cases it is only feasible to undertake the first step in LCA, identifying and inventorying environmental impacts over the life cycle of a product. Where LCA is integrated in quantitative terms with accounting information, however, it can be a very powerful tool for identifying opportunities to reduce environmental impacts in the most cost-effective manner, or even for identifying potential cost savings. For example, Procter and Gamble used LCA to determine that the energy needed to warm water when using household cleaners accounted for more than half of the total energy associated with the product (including manufacturing, transportation and disposal). With this information, the company focused on developing "cold water" or "no rinse" liquid cleaners, thereby expanding market share and increasing profits while decreasing adverse environmental impacts.

Basic Steps for Assessing the Costs and Benefits of Pollution Prevention Options

In theory, both full cost accounting and life cycle assessment thinking, at least in qualitative terms, should be a feature in all pollution prevention planning activities. In practice, however, it is not always appropriate (from the company's perspective) to incorporate FCA or to go beyond a qualitative LCA approach. This section therefore focuses on total cost accounting. It provides an overview of the four basic steps involved in assessing the financial aspects and viability of prevention options relative to the status quo, using a TCA approach.

Step 1: Define the decision options. Identify the business objectives and the available technical options that meet these objectives.

Step 2: Identify and understand the costs associated with each option, in order to be able to compile a complete and accurate picture of the real costs associated with all of the available options, including the status quo.

To assist with this task, a preliminary assessment can be conducted in order to exclude costs that are the same for each option. Table C2 provides a checklist for identifying some of the possible costs and sources of data for identifying those costs, categorized under the following headings:

- **Direct costs** – raw material input, labour, etc.
- **Indirect costs** – up-front costs associated with siting and design requirements; operating costs such as training, monitoring, compliance and disposal costs, including those resulting from poor production quality; back-end costs associated with decommissioning, site clean-up or other remediation efforts.
- **Contingent costs** – fines for future regulatory infractions, compensation for future environmental damage and costs associated with future lost days due to production-related employee absence.
- **Less tangible or quantifiable costs** – arising from changes in corporate image, employee morale, customer relations and relations with regulators.
- **External costs** – costs borne by society as a result of the production, use and disposal of a given product or service.

Step 3: Tabulate and summarize the costs identified for each option (including the status quo). These costs can then be used for further financial analysis if necessary, such as determining and comparing the financial performance of each option using capital budgeting and discounted cash-flow techniques. Sometimes it may be necessary to use activity-based costing techniques to assign identified costs correctly to the appropriate products and processes. The costs of different options compared to the status quo can be displayed, revealing potential savings from each option, all other considerations being equal.

Table C2: Checklist of Possible Potential Costs and Sources of Data for Identifying Them

Type of Cost	Internal Source	External Source
Direct Costs • *Capital costs* e.g., equipment purchases, spare parts and insurance; materials for installation; utility systems and connections • *Operating costs* e.g., materials purchase, transport and storage; labour, including inspections; utilities • *Costs associated with changes in revenue generation* e.g., increase or decrease in product sales due to changes in manufacturing throughput/production	• purchasing • individual facilities • sponsoring business unit • accounting • project management	• proposals/bids • price lists
Indirect Costs • *Capital costs* e.g., fees relating to permits including labour, supervision and materials; site preparation, including demolition and salvage; installation and construction, including design and procurements costs; training; working capital; contingency • *Operating costs* e.g., marketing and public relations; management of non-product outputs, including emergency planning, reuse, hauling and disposal, tracking/info system, storage; regulatory compliance including training, reporting, fees/taxes, site closure and reclamation; insurance • *Costs associated with changes in revenue generation* e.g., by-product sales	• sponsoring business unit or department • related business units • individual facilities • environmental staff • accounting • legal department • project management	• case/benchmarking studies within the same industry • case/benchmarking studies in different industries with similar issues • research institutions
Contingent Costs • *Future liability costs* e.g., fines, penalties, legal proceedings, personal injury claims, property damage claims, natural resource damages and site remediation • *Production losses* e.g., from accidents or clean-up	• environmental staff • legal department • systems operations	• case/benchmarking studies • databases of failure information • original equipment manufacturer failure rates • regulators
Less Tangible or Quantifiable Costs • *Strategic issues leading to an increase or decrease in market share* e.g., corporate image, customer satisfaction and relations; product quality or certification; employee and community relations; employee and community health and safety • *Strategic issues leading to new revenue streams* e.g., flexibility to market new products; innovation	• all business units • corporate comptroller • environmental staff • legal department	

Table C2: Checklist of Possible Potential Costs and Sources of Data for Identifying Them *(continued)*

Type of Cost	Internal Source	External Source
• *Strategic issues leading to more efficient operations* e.g., investor relations; credit ratings; employee relations; employee health and safety; relations with regulators, lenders and insurers; reliability or production capability; innovation		• case/benchmarking studies of companies that have a track record of decisions in the face of high "image" costs • industry associations • studies of stock market reaction to environmental incidents
External Costs • Current societal costs associated with production, use and disposal of product and service	• environmental staff • occupational health and safety/personnel	• Workers Compensation Boards • government databases • hospital and other health-related organizations' studies • reported losses by other sectors of society

Source: Adapted from *Total Cost Assessment Guidelines*, Draft, June 1997.

Step 4: Incorporate the cost information into the business decision making process. The above financial evaluation should be weighed with business and technical considerations to decide which pollution prevention option(s) to adopt.

In conducting this analysis, it is important to identify and distinguish one-time implementation costs and continuing costs related to production and service delivery. This will be particularly relevant, for example, if a multi-year cash-flow analysis is carried out for each option and for the status quo.

An example using these four steps has been provided.

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Type of Cost	Internal Source	External Source
• *Strategic issues leading to more efficient operations* e.g., investor relations; credit ratings; employee relations; employee health and safety; relations with regulators, lenders and insurers; reliability or production capability; innovation		• case/benchmarking studies of companies that have a track record of decisions in the face of high "image" costs • industry associations • studies of stock market reaction to environmental incidents
External Costs • Current societal costs associated with production, use and disposal of product and service	• environmental staff • occupational health and safety/personnel	• Workers Compensation Boards • government databases • hospital and other health-related organizations' studies • reported losses by other sectors of society

Source: Adapted from *Total Cost Assessment Guidelines*. Draft, June 1997

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An example using these four steps has been provided.

Example of Assessing the Costs and Benefits of Pollution Prevention Options Using a Total Cost Accounting Approach

The enterprise: small circuit-board manufacturer, making 100,000 square feet of product per year; 30 employees, 1 responsible for environmental management

Strategic business goal related to the environment: to reduce the use and generation of hazardous materials and "non-product" outputs by 50%, while improving customer satisfaction

P2 planning exercise: identified an opportunity to reduce the use of a hazardous/toxic substance in the workplace

Existing process: circuit–board panels undergo a number of plating and rinsing processes; panels are carried on stainless steel racks, which must be rinsed with the hazardous/toxic substance after each plating run

P2 option: copper-splined, plastic-coated racks eliminate the need for rinsing and support a more even distribution of electrical current, resulting in a more accurate and consistent plating process, leading to improved customer satisfaction

TCA Step 1: Define the decision options – are there compelling reasons for considering alternative options to the status quo, financial or otherwise?

- beyond financial performance, the P2 option would address the strategic business goal stated above

TCA Step 2: Understand and identify costs – what would change as a result of this option?

- examples of direct financial considerations: cost savings in purchasing, storage, handling and recycling the hazardous/toxic substance currently used as a rinsing agent; productivity improvements (no longer need to strip racks after plating runs)
- indirect cost considerations directly attributable to the option: reduction in environmental reporting/tracking; health and safety training and equipment; savings in purchasing and inventory management; reductions in energy and water use
- contingent cost considerations: removal of the hazardous/toxic substance from the workplace; reduction in future liabilities such as fines, penalties and personal injury claims; improved employee and community relations; employee health and safety
- less quantifiable costs: customer satisfaction and potential for improved market share over and above financial benefits associated with reduced product defects

TCA Step 3: Summarize and compare the financial implications of the plastic-coated rack investment relative to the status quo.

- state assumptions such as expected days of operation per year; useful life of rack; inflation rates; discount rate; corporate income tax rate, etc.
- calculate costs and benefits using a number of scenarios that increase and decrease each of the rates stated in the assumptions, both individually and simultaneously

TCA Step 4: Integrate financial cost and benefit information with other business and technical considerations to decide whether to implement the plastic-coated rack option.

References and Resources

For more information on pollution prevention and pollution prevention planning:

Canadian Pollution Prevention Information Clearinghouse: www.ec.gc.ca/cppic

Canadian Centre for Pollution Prevention: www.c2p2online.com

Canadian Environmental Protection Act, 1999: www.ec.gc.ca/CEPARegistry

Your Environment Canada Regional Office.

For a general overview on accounting for environmental costs and benefits:

Introductory Guide to Environmental Accounting. Environment Canada, Ottawa, 1999

Other sources of assistance in environmental cost accounting:

The USEPA Environmental Accounting Project: www.epa.gov/opptintr/acctg

The Green Ledgers publication of the World Resources Institute in Washington, D.C., provides practical steps for integrating environmental accounting practices into existing business systems

The Canadian Institute of Chartered Accountants (CICA) has published studies in environmental performance reporting, waste management guidelines and full cost accounting: www.cica.ca

The Society of Management Accountants of Canada (SMAC) has published guides on business strategy, performance measurement and accounting for environmental costs: www.cma-canada.org

For more information on life cycle assessment:

Environmental Life Cycle Management: A Guide to Better Business Decisions. Environment Canada, 1997 (For an overview of the Guide, see www.ec.gc.ca/ecocycle/english/lcmguide.html

Various free LCA software tools available on the Internet, including:

- The U.S. National Institute of Standards and Technology's LCA decision-support software for buildings called Buildings for Environmental and Economic Sustainability: www.bfrl.nist.gov/oae/software/bees.html
- Carnegie Mellon University Green Design Initiative's Economic Input-Output Lifecycle Assessment (EIOLCA) software: www.eiolca.net
- In the fall of 2000, the U.S. Environmental Protection Agency will open LCAccess, a free, web-based searchable directory of life cycle inventory data: www.epa.gov/ord/nrmrl/std/sab/lca_access.htm

The ISO 14040 series of guidance documents.

POLLUTION PREVENTION PRACTICES

Appendix D: Product Design and Reformulation

Introduction

This information sheet introduces design for environment (DfE) methods for preventing pollution through the design of new products and the reformulation of existing ones. The product design stage is a crucial starting point for implementing pollution prevention. Addressing concerns associated with the product from the earliest stage is often the most cost-effective way to avoid environmental impacts associated with the production, use and disposal of a product.

Pollution prevention is "the use of processes, practices, materials, products, substances or energy that avoid or minimize the creation of pollutants and waste, and reduce the overall risk to the environment and human health" (*Canadian Environmental Protection Act, 1999*). Pollution prevention is at the top of a hierarchy of environmental protection methods that also include off-site reuse and recycling, pollution control or treatment, disposal/destruction, remediation and clean-up. While all environmental protection methods provide some benefits, pollution prevention can provide the most cost-effective opportunities for reducing environmental and health risks while improving a business's bottom line.

DfE and Life Cycle Analysis

DfE seeks to integrate environmental criteria into the usual design drivers of performance, cost, quality, cultural, legal and technical criteria. It does so by starting with an analysis of the product life cycle. For simplicity, the product life cycle after the design stage can be categorized into five stages:

- raw material acquisition and processing (this includes extracting and refining non-renewable raw materials, and harvesting and processing renewable resources);
- manufacturing and production;
- filling, packaging and distribution;
- use, reuse and maintenance; and
- disposal.

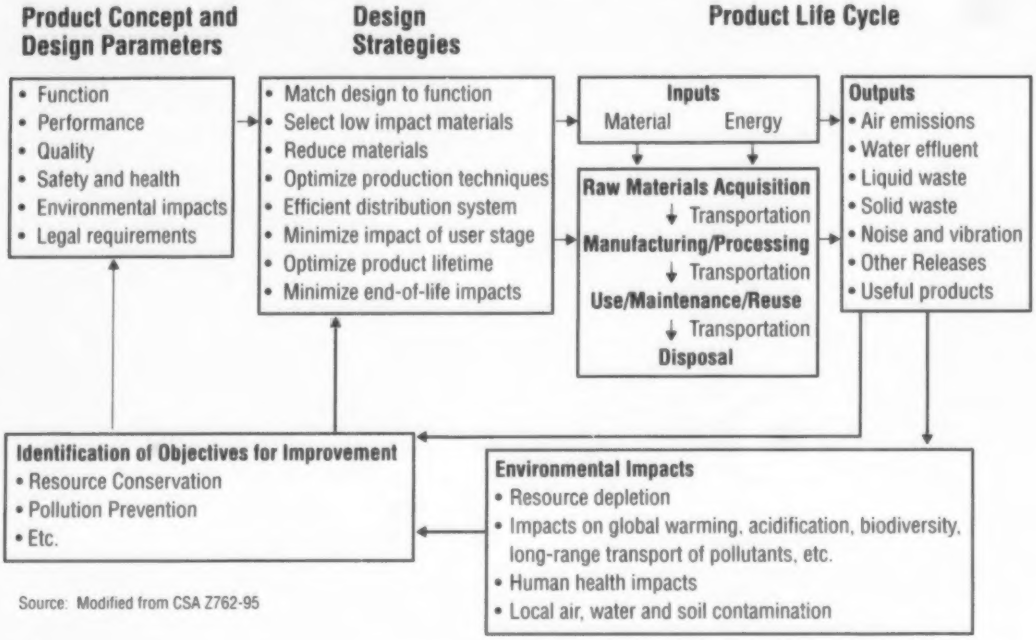
From this life cycle perspective, DfE can involve reducing the toxicity of a product, extending the life of a product, extending the life of the materials used, improving the selection of materials, and reducing the energy and material intensity required to produce, use and dispose of the product.

Figure D1 illustrates the relationship between the design process and the overall life cycle environmental impacts of a product.

In identifying opportunities for reducing environmental impacts along the life cycle of a product, DfE incorporates product and process design into one analysis, as opposed to designing the product first, and then considering the process by which it will be produced. Such integration is obviously not always easy. It requires an iterative and creative approach. Identifying the full range of impacts (environmental and otherwise) of a possible design across the life cycle of a product can require a significant amount of information. Products, especially durable products, are made of increasingly sophisticated materials. Assessing the environmental attributes of these materials is difficult, and is even more so where suppliers of components and subassemblies are widely dispersed. Accounting for these considerations concurrently with all other relevant design objectives and considerations can be challenging.

Properly done, however, DfE can bring numerous important benefits. Because products are the focal point in a complex web of material and energy flows, an emphasis on DfE requires an organization to take a systems perspective. In turn, this:

Figure D1: Relationship Between a Product's Design and Its Life Cycle Impacts


Product Concept and Design Parameters
Design Strategies
Product Life Cycle
• Function
• Performance
• Quality
• Safety and health
• Environmental impacts
• Legal requirements
• Match design to function
• Select low impact materials
• Reduce materials
• Optimize production techniques
• Efficient distribution system
• Minimize impact of user stage
• Optimize product lifetime
• Minimize end-of-life impacts
Inputs
Material
Energy
Raw Materials Acquisition
Transportation
Manufacturing/Processing
Transportation
Use/Maintenance/Reuse
Transportation
Disposal
Outputs
• Air emissions
• Water effluent
• Liquid waste
• Solid waste
• Noise and vibration
• Other Releases
• Useful products
Identification of Objectives for Improvement
• Resource Conservation
• Pollution Prevention
• Etc.
Environmental Impacts
• Resource depletion
• Impacts on global warming, acidification, biodiversity, long-range transport of pollutants, etc.
• Human health impacts
• Local air, water and soil contamination

Source: Modified from CSA Z762-95

- ties environmental issues directly to the core business activity of a company;
- allows a company to identify where it can get the best return on investment for its environmental expenditure; and
- enables environmental issues to become a means to reduce costs, maintain market access, gain competitive advantage, enhance brand image and increase revenues.

Figure D2 illustrates the different types of design considerations relevant to each stage in a typical product's life cycle and lists possible design objectives relevant to preventing the environmental impacts associated with each stage. Stages 2 to 5 focus on reducing the pollution associated with producing and distributing products. Information on practices for preventing pollution during these stages can be found in Appendices E, "Equipment Modifications and Process Changes"; F, "Materials and Feedstock Substitution"; G, "Operating Efficiencies and Training"; H, "Purchasing Techniques and Inventory Management" and I, "On-Site Reuse and Recycling."

The remainder of this appendix focuses on extending product design considerations both upstream of the production phase (life cycle stage 1 of Figure D2) and downstream of the distribution phase (life cycle stages 6 to 8 of Figure D2).

Upstream Considerations: Emphasizing Functional Optimization in New Concept Development

A product can be designed only once its functional objectives have been established. One of the key insights with respect to DfE is

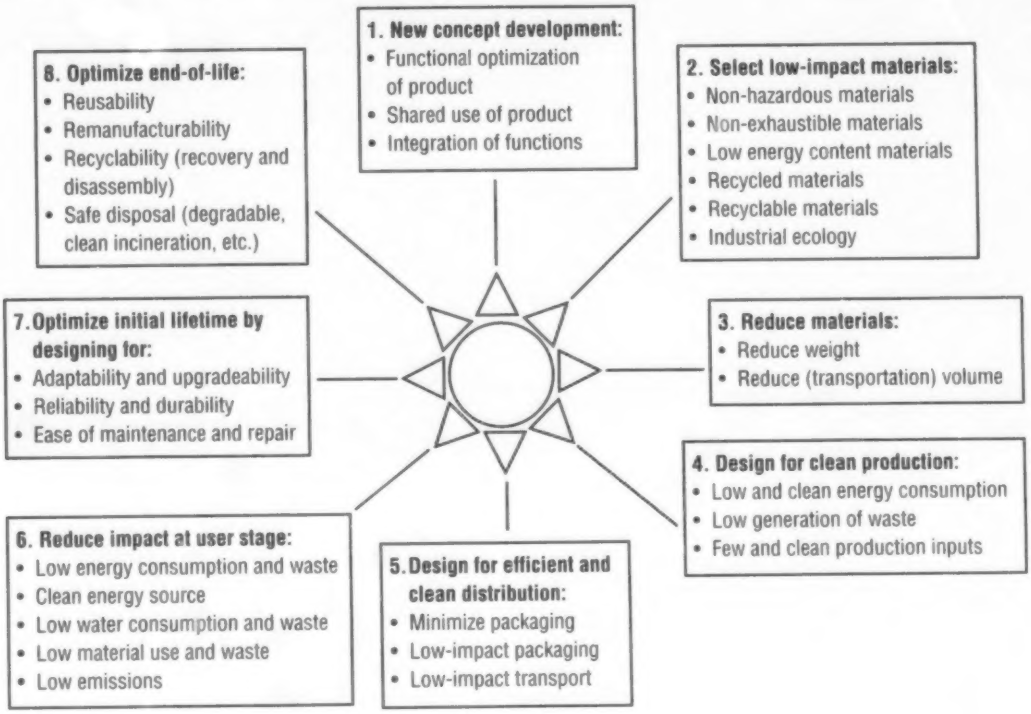


Figure D2: DfE Opportunities Throughout the Product Life Cycle

1. New concept development:
- Functional optimization of product
- Shared use of product
- Integration of functions

2. Select low-impact materials:
- Non-hazardous materials
- Non-exhaustible materials
- Low energy content materials
- Recycled materials
- Recyclable materials
- Industrial ecology

3. Reduce materials:
- Reduce weight
- Reduce (transportation) volume

4. Design for clean production:
- Low and clean energy consumption
- Low generation of waste
- Few and clean production inputs

5. Design for efficient and clean distribution:
- Minimize packaging
- Low-impact packaging
- Low-impact transport

6. Reduce impact at user stage:
- Low energy consumption and waste
- Clean energy source
- Low water consumption and waste
- Low material use and waste
- Low emissions

7. Optimize initial lifetime by designing for:
- Adaptability and upgradeability
- Reliability and durability
- Ease of maintenance and repair

8. Optimize end-of-life:
- Reusability
- Remanufacturability
- Recyclability (recovery and disassembly)
- Safe disposal (degradable, clean incineration, etc.)

Source: Adapted from the Life Cycle Design Strategy (LiDS) Wheel developed by the Netherlands' PROMISE project.

that environmental and functionality objectives can often be met by rethinking the *functions* customers want from products and redefining those needs in ways that have less environmental impact. This entails a shift in thinking, from what nuts and bolts to provide to the customer to what service or benefit the customer actually wants. In addition to encouraging designers to step back from their traditional design focus, this concept has prompted a growing number of companies to maintain ownership of their products and sell product services instead. Examples include companies that provide elevator services, washing machine services and flooring services. This shift has created external incentives to compete on the basis of service and internal incentives to enhance the durability, serviceability, ease of upgrading and ease of disposal of products provided to customers.

Downstream Impacts: The User Stage and After

Design for Minimal Impact at the User Stage

Some products create significant environmental impacts while being used. For products such as motor vehicles, some of the most important pollution prevention opportunities can result from designs that reduce energy and resource use requirements and that minimize emissions during the user stage.

Optimize Initial Lifetime

The initial lifetime of a product can be optimized by designing the product to be reliable, durable, adaptable and serviceable.

Reliability

Reliability is a major aspect of quality. Unreliable products or processes, even if they are durable, are often quickly retired. Reliability should be designed into products, rather than achieved through later inspection. Screening out potentially unreliable products or components after they are made is wasteful because such products and components must either be repaired or discarded.

Durability
Some design options may make a product more durable without the use of additional resources. In other cases, however, enhanced durability may require increased resource use. In these cases, a trade-off will be required between the benefits of increased product life and an increase in resource use. Similarly, it is important to design a product or component that does not last longer than its expected useful life in the marketplace. For example, products based on rapidly changing technology may not be good candidates for enhanced durability.

Adaptability and Ease of Upgrading
Adaptable designs either allow continual updating or perform several different functions. Modular components allow single-function products to evolve and improve as needed. For components to be interchangeable, their dimensions and tolerances must be carefully controlled. To have a significant environmental benefit, upgrading must retain a sufficient portion of the original product after obsolete parts are replaced.

Serviceability
Design efforts to enhance serviceability will work best if efforts are also made to ensure that potential users have access to the necessary skills, tools and parts. The development and use of standardized parts can make products easier to repair and therefore extend their life.

Optimize End-of-Life

The environmental impacts associated with a product at the end of its intended life can be reduced by designing for reuse, remanufacturing, recycling or safe disposal.

Interface Flooring Systems (Canada) Inc. in Belleville, Ontario, reduced the weight of the backing on its nylon carpet tiles. The result was a better product as well as environmental benefits. By having less material in the backing, the product achieved better smoke and flame ratings and improved quality performance. The production process also uses less fuel (plasticisers and polymers), resulting in lower emissions of volatile organic compounds (VOCs). Furthermore, by reducing the amount of material in the carpet backing, Interface was able to decrease the amount of heat required to laminate the face and backing, which also led to energy savings and an improved product. The overall environmental benefits of this product reformulation included a reduction in raw material and energy use as well as a reduction in solid waste and VOC emissions. This reformulation also provided economic benefits by improving product quality and performance, reducing material and energy costs, improving operating revenues, and reducing solid waste and disposal costs.

Source: www.ec.gc.ca/[illegible]

Design for Reuse
In many cases, designing a product to be reusable can significantly lower the pollution associated with its overall life cycle. Where the main environmental impact comes from the product's manufacture, reuse will lower its overall life cycle impacts. Where significant environmental impacts are associated with its distribution, collection and cleaning, however, designing for reusability may have little or even negative overall environmental impacts.

Design for Remanufacturing
Remanufacturing is the restoration of used products or components to a condition with

performance characteristics approximating those of a new product. It extends product life and promotes the reuse of components and materials. It can enhance the value of the original product by giving it value after the end of its initial life. Industrial equipment or other expensive products not subject to rapid change are the best candidates for remanufacture. For example, remanufacturing is widely used in the automotive and industrial equipment sectors. The following factors are relevant to its applicability:

- The product intended for remanufacture should be:
    - mature (not undergoing rapid change in design or materials);
    - standardized and made with interchangeable parts; and
    - easily disassembled.
- Component parts must be capable of repair and refurbishment to enable the final remanufactured product to replicate the original performance.
- The end-of-life product must have a "core" that retains sufficient value to justify remanufacture.
- There should be a sufficient population of old units (cores) with an available (or easily established) trade-in network and storage and inventory infrastructure.

Design for Recycling

Design for recycling comprises two streams: recovery and disassembly.

- **Design for recovery** exploits existing technology for material recovery such as scrap metal shredding. Design features that can improve recovery include:
    - using easily recycled materials;
    - avoiding self-contaminating combinations of materials (e.g., copper contamination of steel can reduce the recovery value of steel); and
    - eliminating or avoiding toxic substances that may not be accepted for shredding (e.g., cadmium, asbestos, mercury).

In order to allow for the efficient separation of materials following the end of a product's initial life, the following principles should be considered:

- Minimize material variety and use compatible materials.
- Consolidate parts and minimize the number of components.
- Reduce the number of assembly operations.
- Identify separation points between parts.
- Mark materials.
- Mould recycling codes into plastic to streamline disassembly.
- Use water-soluble adhesives, where possible.
- Ensure that separation at break points cannot occur inadvertently.
- Avoid metal contamination of plastics.
- Avoid composite materials such as fibreglass.
- Eliminate or avoid toxic materials and other hazardous substances.
- Use snap fittings and simplify and standardize component fits and interfaces.
- Use the material required; avoid over-specifying materials.
- Use colorants sparingly and allow for easy separation of differently coloured plastics.
- Avoid secondary coatings, finishes and platings.
- Provide information on recyclability to the end user.
- Design with the recovery system in mind.

- **Design for disassembly** enables the recycling of almost all materials (including plastics) in a product through its disassembly into basic components. Materials other than metals can be recovered only through disassembly, which keeps them free from contamination and therefore retains their original properties.

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Source: www.ec.gc.ca/pp/en/storyoutput.cfm?storyID=42

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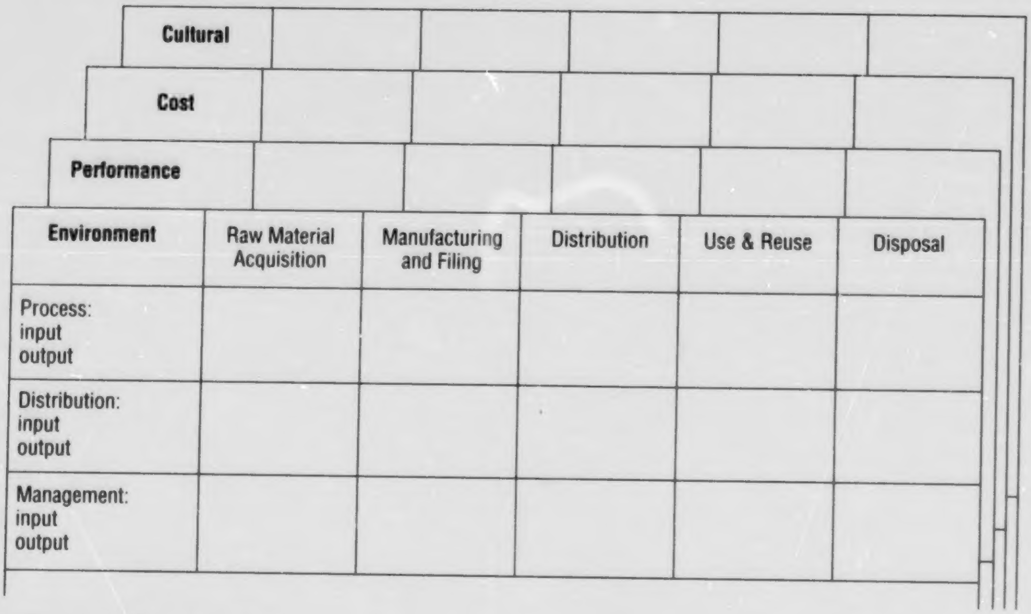
Figure D3: Conceptual DfE Requirements Matrix



Environment	Raw Material Acquisition	Manufacturing and Filing	Distribution	Use & Reuse	Disposal
Process: input output					
Distribution: input output					
Management: input output					

Design for Safe Disposal

Finally, product design should ensure that the materials used in a product can be safely disposed of, where they cannot be reused or recycled. Relevant considerations include, for example, specifying materials that are degradable or that can be incinerated cleanly.

Implementing DfE Through a Requirements Matrix

There are several tools available to support DfE. One useful approach, known as a requirements matrix, helps the design team establish the requirements for the design of a product. It allows the presentation, assessment and comparison of several requirements simultaneously. A typical requirements matrix (see Figure D3) includes analysis of the environmental, performance, cost, cultural and legal requirements of the product system. The inputs and outputs associated with each component of the product system (i.e., the product, production process, distribution system and management system) are discussed and then evaluated by the design team.

As an example, the following type of information could be relevant for completing a DfE requirements matrix for the development of a new car:

- The **environmental requirements** of a car could include improved worker health and safety considerations during production, limited use of non-renewable resources in the car's manufacture, and ease of disassembly and recycling at the end of its life.
- The **performance requirements** define the function of the product in question and, in this case, could include fuel efficiency, tolerance to collision, passenger and storage capacity and rough-road driving capabilities.
- **Cost considerations** could include the customer purchase price of the car, cost of servicing and maintaining the vehicle, as well as the cost of appropriate disposal.
- **Cultural considerations** of the car could include size, shape and colour, depending upon where and when the vehicle is being marketed and sold.

- Finally, relevant **legal requirements** could include factors such as emissions standards, safety features and end-of-life disposal.

Reformulating an Existing Product for Pollution Prevention

The concepts described above for initial product design can also be applied to redesign and reformulate existing products to prevent pollution associated with their production, use and disposal. This need not entail a complete redesign of the product. Simply changing one or more product specification or component can accomplish a great deal. One spectacular success in this area was the reformulation of laundry detergents to remove the phosphates that were responsible for the eutrophication of many lakes until the 1970s. Another example is the removal of mercury from many products like fluorescent light ballasts and household thermostats. In both cases, products were reformulated to significantly reduce pollution while retaining the full functionality of the original product.

References and Resources

For more information about pollution prevention and pollution prevention planning:

Canadian Pollution Prevention Information Clearinghouse: www.ec.gc.ca/cppic

Freeman, Harry, 1995. *Industrial Pollution Prevention Handbook*, McGraw-Hill

Canadian Environmental Protection Act, 1999: www.ec.gc.ca/CEPARegistry

Your Environment Canada Regional Office.

For more information about DfE:

The Industrial Research Assistance Program (IRAP) of the National Research Council of Canada:

- IRAP has designed a succinct guide to DfE that has been adapted for inclusion on their DfE Internet site. This site uses information retrieval software developed by the Canada Institute for Scientific and Technical Information that links users to numerous DfE references and source materials: www.nrc.ca/dfe
- IRAP is also training its industrial technology advisors to help small and medium sized businesses develop more strategic and environmentally responsible initiatives by relying on IRAP's DfE guide and website: www.nrc.ca/irap
- The National Research Council's main website: www.nrc.ca

The U.S. Environmental Protection Agency's Office of Pollution Prevention and Toxics runs a "Design for Environment" program. The DfE program website provides information about various DfE assessment tools as well as links to other resources: www.epa.gov/opptintr/dfe

The U.S. Environmental Protection Agency's DfE program website introduces the Cleaner Technologies Substitutes Assessment (CTSA): A Methodology and Resource Guide (EPA744-R-95-002). The CTSA approach facilitates comparisons of the risk, cost and performance of alternative products, processes and technologies. It relies on the Use Clusters Scoring System (UCSS) to identify and analyze groups of chemicals for various tasks with respect to human health, environment and safety risks: www.epa.gov/opptintr/dfe/tools/ctsa/contents.htm

The U.S. Department of Energy's "Sustainable Design" website contains useful information and tools: www.pnl.gov/doesustainabledesign

Design for Recyclability, GE Plastics, Worldwide Headquarters, One Plastics Avenue, Pittsfield, MA 011201, U.S.A.

Design for Recyclability, Michael Henstock, The Institute of Metals, Carlton House Terrace, London SW1YSDB, U.K.

CSA Z762-95 *Design for the Environment*, Canadian Standards Association, 178 Rexdale Blvd., Etobicoke, Ontario, M9W 1R3

EcoRedesign Newsletter, Centre for Design, Royal Melbourne Institute of Technology: www.cfd.rmit.edu.au

Centre for Sustainable Design/*Journal of Sustainable Design*: www.cfsd.org.uk

United Nations Environment Program: Working Group on Sustainable Product Development: http://unep.frw.uva.nl

For more information on life cycle assessment:

Environmental Life Cycle Management: A Guide to Better Business Decisions. Environment Canada, 1997 (For an overview of the Guide, see www.ec.gc.ca/ecocycle/english/lcmguide.html

Various free LCA software tools available on the Internet, including:

- The U.S. National Institute of Standards and Technology's LCA decision-support software for buildings called Buildings for Environmental and Economic Sustainability: www.bfrl.nist.gov/oae/software/bees.html
- Carnegie Mellon University Green Design Initiative's Economic Input-Output Lifecycle Assessment (EIOLCA) software: www.eiolca.net
- In the fall of 2000, the U.S. Environmental Protection Agency will open LCAccess, a free, web-based searchable directory of life cycle inventory data: www.epa.gov/ord/nrmrl/std/sab/lca_access.htm

The ISO 14040 series of guidance documents.

Product Design Pollution Prevention Checklist

Life Cycle Stage	Relevant Considerations	✓
Ensure design flows from clear understanding of desired function	• Focus on function? • Evaluate past? • Learn from mistakes? • Identify opportunities for improvement?	
Ensure appropriate material selection	• Low-impact materials? • Minimize materials?	
Ensure clean production	• Energy-efficient production? • Material-efficient production? • Low-waste production? • Minimize need to release toxics and other harmful substances during production?	
Ensure efficient and clean distribution and packaging	• Design for efficient and clean distribution? • Minimize packaging? • Specify clean packaging?	
Minimize impacts at user stage	• Low energy consumption? • Reliance on clean energy? • Low water consumption and waste? • Low material use? • Low waste generation? • Low emissions?	
Optimize initial lifetime	• Reliable? • Durable? • Adaptable and upgradeable? • Serviceable?	
Optimize end-of-life	• Reuseable? • Remanufacturable? • Recyclable? • Recoverable? • Ability to be disassembled? • Safely disposable?	
Reformulate existing product for continuous improvement		

Appendix E: Equipment Modifications and Process Changes

Introduction

Most processing and manufacturing companies are engaged in continuous efforts to enhance efficiency or improve quality through modifications to their equipment and processes. This information sheet outlines various ways to ensure that such modifications and changes also contribute to pollution prevention. In addition, it provides examples and presents a checklist to help implement these practices.

Pollution prevention is "the use of processes, practices, materials, products, substances or energy that avoid or minimize the creation of pollutants and waste, and reduce the overall risk to the environment and human health" (*Canadian Environmental Protection Act, 1999*). Pollution prevention is at the top of a hierarchy of environmental protection methods that also include off-site reuse and recycling, pollution control or treatment, disposal/destruction, remediation and clean-up. While all environmental protection methods provide some benefits, pollution prevention can provide the most cost-effective opportunities for reducing environmental and health risks while improving a business's bottom line.

In operating production or processing systems, the aim is typically to optimize the system in terms of production efficiency and end-product quality. However, it is often the case that production systems operate in a manner that wastes energy or generates unnecessary toxic or other non-product outputs (wastes). By modifying equipment or production processes, much can be done to reduce, prevent or even eliminate pollution. Such changes can often increase profits, enhance production efficiency and reduce permitting, storage, waste disposal and recycling costs.

Interface Flooring Systems (Canada) Inc. in Belleville, Ontario, modified its manufacturing process for nylon carpet tiles to eliminate the conventional printing process. Rather than being printed, designs are now incorporated into the carpet at the tufting stage itself. The print line and its associated pollution control equipment were eliminated, as were charges to the customer for printing. Energy is no longer needed for steaming and drying. Water is no longer required for carpet washing, and wash effluent has been eliminated. The company also replaced its cooling tower with a second-hand chiller unit. Environmental benefits include zero process effluent; a reduction in water use of 430 m^3 a month; the elimination of heavy metals from the production process; and reductions in energy consumption of 35% and atmospheric emissions of 38%. Economic benefits include savings of $8,000 a month ($96,000 a year) in water and sewer charges; a 35% reduction in energy costs (peak load charges were reduced by over 30%); a 6% reduction in raw material use; a reduction in off-quality product; and an increase in operating revenues.

Source: www.ec.gc.ca/pp/en/storyoutput.cfm?storyID=43

Implementing Equipment Modifications and Process Changes

Most businesses and industries can make equipment modifications or process changes to improve pollution prevention. Depending on the organization, specific prevention opportunities may focus on issues related to chemicals, metals, safety, water or energy. Home offices and office buildings may make use of only water and energy

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Table E1: Equipment Modification and Process Change Opportunities to Reduce Pollution from Metals Stripping

Conventional Technology	Replacement Technology	Coating Removal Performance	Operating Simplicity	Relative Capital Costs	Relative Operating Costs	Environmental Health and Safety Risk
Abrasive blasting;	Blasting substitutes	Same	Same	Same	Same	Same/Less
Chlorinated substances		Same/Less	Better	Less	Less	Less
Abrasive blasting;	High-pressure water	Better	Same	More	Same	Less
Grinding;		Better	Better	More	Same	Less
Chlorinated substances		Better	Same	More	Less	Less
Abrasive blasting;	Organic solvents	Better	Better	Less	Less	Same/Less
Chlorinated substances		Same/Less	Same	Same	Same/Less	Less

audits, while laboratories, manufacturing plants and petroleum refineries may apply any number of pollution prevention practices to identify and implement economical pollution prevention measures.

Chemicals

The metal fabrication industry typically supplies the automotive, defence, electronics, appliance and furniture industries with a broad range of components. The production processes associated with this industry are varied, and involve the use of numerous chemical compounds. In an assessment of 2,900 facilities in the metal fabrication industry in the United States, for example, some 195 million pounds (88 million kg) of chemicals were registered, falling into over 100 chemical groups (Freeman, 1995). There are five common processing operations in the metal products industry that can be identified as major sources of pollution generation and discharge: stripping, painting, cleaning, inorganic surface treatment, and inorganic surface finishing. Stripping, painting and cleaning are important sources of volatile organic compounds (VOCs) and ozone-depleting substances (ODSs), while inorganic surface treatment and surface finishing are sources of acids and metals.

Stripping and cleaning traditionally involve the use of abrasive blasting technologies to physically remove paints and other organic coatings from metal surfaces. Another method of stripping and painting entails the use of chemicals and solvents to soften coatings before they are removed from a surface mechanically. Due to the types of chemical and, in particular, solvents used in these processes, high levels of VOCs, ODSs, and solid and liquid wastes are generated. In addition, explosions and fire hazards are often associated with these materials.

Prior to 1988, one of Nortel Networks' manufacturing processes used a CFC-113 based solvent to clean excess flux from the soldering process. Upon examination of alternatives for replacing the solvent, a "no clean" system was developed, which eliminated the cleaning step entirely. By the end of 1991, all Nortel facilities involved in the program had eliminated the use of CFC-113 solvents. Seven other facilities eliminated the use of CFC-113 solvents by mid-1992. Between 1988 and 1991, Nortel reduced its use of CFC-113 by 1 million kilograms for a savings of $4 million, with a development investment of $1 million.

Source: www.ec.gc.ca/pp/en/storyoutput.cfm?storyID=50

Using the latest distillation technology to capture and recycle on-site all cleaning solvents, King Metal Fabricators Ltd. of Nova Scotia reduced by 95%, the amount of solvent purchased and disposed of as a hazardous waste, resulting in a savings of approximately $16,000 a year. The company also installed a "self-recycling" blast booth that uses steel shot and grit as the blast medium, in place of sand. Shot can be used up to 200 times, whereas sand can be used only twice. The booth recycles the shot automatically by collecting, cleaning and returning it to the blast pot, eliminating the generation of waste sand from the blasting process. The finishing operation now takes 50% less time, saving approximately $12,000 a year in labour costs.

There are, however, several equipment modifications and process changes that reduce or eliminate the need for toxic compounds and, at the same time, reduce operational costs and worker heath and safety risks. Table E1 summarizes these opportunities for paint stripping.

Metals

The electroplating industry deals with the manufacture of strategic and consumer products, including printed circuit boards and automotive parts. Electroplating utilizes a wide range of chemicals, depending upon the types of metals processed for electroplating and the types of metallic coating being applied. In addition, compounds containing heavy metals are often used in the plating process. These are of considerable environmental concern.

For this sector, pollution prevention alternatives through equipment modification and process change options include the addition of electrolytic recovery and ion exchange technologies to existing systems. Electrolytic recovery, for instance, is a technology that uses special electroplating equipment to lower the concentration of dissolved metals in drag-out rinses and concentrated rinse tanks. Benefits of this technology include reduced generation of sludge, some electrolyte destruction of cyanide, and reuse or sale of scrap metal plated out.

Plouffe Park, a 31,258 m^2 federal government building, used 20,400 m^3 of water at a cost of $18,779 in 1998. In 1999, a water audit was performed for approximately $5,000. The resulting simple equipment modifications (e.g., motion-detected flushing urinals in place of continuous flush urinals) have reduced water consumption by 40%, saving $7,000 per year.

Source: From the experiences of Jacques Whitford Environment Ltd.

Water

Water management strategies to promote pollution prevention include water and wastewater flow reduction; recycling; by-product recovery; and water reuse. Water usage can be minimized through practices such as:

- using high-pressure hoses or spray rinses instead of dip tanks;
- replacing water curtain spray paint booths with an electrostatic painting system;
- replacing a water-cooled heat exchange system with an air-cooled system;
- replacing a cooling tower with a refrigerant-based cooling system; and
- replacing a wet scrubber with a bag house.

Where changes in operations are concerned, practices to reduce water wastage can be grouped into three main objectives: optimize equipment cleaning operations; maximize the effective life of production water; and optimize water usage. Table E2 illustrates examples of operational changes toward each of these objectives.

[illegible]

Conventional Technology	Replacement Technology	Coating Removal Performance	Operating Simplicity	Relative Capital Costs	Relative Operating Costs	Environmental Health and Safety Risk
Abrasive blasting; Chlorinated substances	Blasting substitutes	Same Same/Less	Same Better	Same Less	Same Less	Same/Less Less
Abrasive blasting;	High-pressure water	Better	Same	More	Same	Less
Grinding;		Better	Better	More	Same	Less
Chlorinated substances		Better	Same	More	Less	Less
Abrasive blasting; Chlorinated substances	Organic solvents	Better Same/Less	Better Same	Less Same	Less Same/Less	Same/Less Less

audits, while laboratories, manufacturing plants and petroleum refineries may apply any number of pollution prevention practices to identify and implement economical pollution prevention measures.

Chemicals

The metal fabrication industry typically supplies the automotive, defence, electronics, appliance and furniture industries with a broad range of components. The production processes associated with this industry are varied, and involve the use of numerous chemical compounds. In an assessment of 2,900 facilities in the metal fabrication industry in the United States, for example, some 195 million pounds (88 million kg) of chemicals were registered, falling into over 100 chemical groups (Freeman, 1995). There are five common processing operations in the metal products industry that can be identified as major sources of pollution generation and discharge: stripping, painting, cleaning, inorganic surface treatment, and inorganic surface finishing. Stripping, painting and cleaning are important sources of volatile organic compounds (VOCs) and ozone-depleting substances (ODSs), while inorganic surface treatment and surface finishing are sources of acids and metals.

Stripping and cleaning traditionally involve the use of abrasive blasting technologies to physically remove paints and other organic coatings from metal surfaces. Another method of stripping and painting entails the use of chemicals and solvents to soften coatings before they are removed from a surface mechanically. Due to the types of chemical and, in particular, solvents used in these processes, high levels of VOCs, ODSs, and solid and liquid wastes are generated. In addition, explosions and fire hazards are often associated with these materials.

Prior to 1988, one of Nortel Networks' manufacturing processes used a CFC-113 based solvent to clean excess flux from the soldering process. Upon examination of alternatives for replacing the solvent, a "no clean" system was developed, which eliminated the cleaning step entirely. By the end of [illegible], all Nortel facilities involved in the program had eliminated the use of CFC-113 solvents. [illegible] facilities eliminated the use of CFC-113 solvents by [illegible]. Between [illegible] and [illegible], Nortel reduced its use of CFC-113 by 1 million kilograms for a savings of [illegible] million, with a development investment of [illegible] million.

[illegible]

Using the latest distillation technology to capture and recycle on-site all cleaning solvents, King Metal Fabricators Ltd. of Nova Scotia reduced by 80%, the amount of solvent purchased and disposed of as a hazardous waste, resulting in a savings of approximately $16,000 a year. The company also installed a "self-recycling" blast booth that uses steel shot and grit as the blast medium, in place of sand. Shot can be used up to 200 times, whereas sand can be used only twice. The booth recycles the shot automatically by collecting, cleaning and returning it to the blast pot, eliminating the generation of waste sand from the blasting process. The finishing operation now takes 30% less time, saving approximately $12,000 a year in labour costs.

There are, however, several equipment modifications and process changes that reduce or eliminate the need for toxic compounds and, at the same time, reduce operational costs and worker heath and safety risks. Table E1 summarizes these opportunities for paint stripping.

Metals

The electroplating industry deals with the manufacture of strategic and consumer products, including printed circuit boards and automotive parts. Electroplating utilizes a wide range of chemicals, depending upon the types of metals processed for electroplating and the types of metallic coating being applied. In addition, compounds containing heavy metals are often used in the plating process. These are of considerable environmental concern.

For this sector, pollution prevention alternatives through equipment modification and process change options include the addition of electrolytic recovery and ion exchange technologies to existing systems. Electrolytic recovery, for instance, is a technology that uses special electroplating equipment to lower the concentration of dissolved metals in drag-out rinses and concentrated rinse tanks. Benefits of this technology include reduced generation of sludge, some electrolyte destruction of cyanide, and reuse or sale of scrap metal plated out.

[illegible] Park, a 31,238 m^2 federal government building, used 38,400 m^3 of water at a cost of $18,779 in 1988. In 1990, a water audit was performed for approximately $5,000. The resulting simple equipment modifications (e.g., motion-detected flushing urinals in place of continuous flush urinals) have reduced water consumption by 40%, saving $7,000 per year.

Source: From the experiences of Jacques Whitford Environment Ltd.

Water

Water management strategies to promote pollution prevention include water and wastewater flow reduction; recycling; by-product recovery; and water reuse. Water usage can be minimized through practices such as:

- using high-pressure hoses or spray rinses instead of dip tanks;
- replacing water curtain spray paint booths with an electrostatic painting system;
- replacing a water-cooled heat exchange system with an air-cooled system;
- replacing a cooling tower with a refrigerant-based cooling system; and
- replacing a wet scrubber with a bag house.

Where changes in operations are concerned, practices to reduce water wastage can be grouped into three main objectives: optimize equipment cleaning operations; maximize the effective life of production water; and optimize water usage. Table E2 illustrates examples of operational changes toward each of these objectives.

Table E2: Operational Changes for Reducing Water Wastage

Objective	Examples of Operational Changes
Optimize equipment cleaning	• Use mechanical cleaning devices, such as rubber wipers, prior to cleaning components with water • Use high-pressure spray heads to increase cleaning efficiency and reduce the amount of water required to remove wastes or dirt • Line tanks with non-stick materials such as Teflon to reduce adhesion and increase drainage • Use countercurrent rinsing cycles • Co-ordinate cleaning schedules • Use plastic or foam "pigs" to clean pipes
Maximize effective life of production water	• Use countercurrent rinsing • Use de-ionized make-up water in rinse tank applications
Optimize water usage	• Improve seals on pumps, pipes and valves • Use automatic flow control equipment • Use water level controls and splash guards • Place lids or [illegible] on tanks • Replace once-through cooling systems with closed-loop systems

The economic and environmental benefits of reducing water use can be significant. Payback periods are usually quick and the savings are often substantial, with low costs for employee training and maintenance.

Safety Assessment

The economic benefits from equipment modifications and process changes undertaken as a result of safety assessments cannot be calculated as easily as in other areas. These changes are often driven by liability and public image incentives (lessening the risk to people and/or the environment), rather than for monetary reasons. However, lost time at work resulting from employee injuries or illness, and savings from any fines resulting from non-compliance disposal may sometimes be monitored. This approach will typically apply more to larger manufacturing facilities and refineries than to office buildings.

Energy

Many technologies are available to enable a plant to use energy more efficiently, leading to a direct reduction in emissions. Typically, plant and process heating relies on steam boilers operating at efficiencies between 75% and 85%. In many cases, proven technologies can improve this efficiency to over 95%. Heat energy (both latent and sensible) leaving with stack gases is the primary heat loss in boiler processes. By recovering and applying this waste heat, a typical natural gas boiler can improve its efficiency by 10% to 15%, reducing annual carbon dioxide, nitrogen oxides and other emissions by the same amount. These technologies can also be applied to humid process exhausts to similar or greater effect.

Over-filling of storage vessels often leads to spills of hazardous materials and expensive clean-up. After this problem was reviewed at a federal heating plant facility, a [illegible] cabinet was purchased and installed. This device has no drain valves, an overflow alarm light and a locking mechanism that a plant employee must unlock and supervise during refuelling. Costing only $[illegible], this simple modification ensures that correct fuelling procedures are followed and protects against costly and environmentally damaging spills.

[illegible]

Key Steps to Implementing Equipment Modifications and Process Changes

The largest barrier to implementing equipment modifications and process changes for pollution prevention is often the capital investment required, especially with the larger processes. A thorough review at the beginning of the process is important to ensure that all options are investigated and compared on a "level playing field." All costs and benefits should be quantified. As with any significant change to equipment or processes, an implementation and monitoring plan will help ensure that any changes made are implemented as effectively as possible, and that any problems that arise are identified and addressed as quickly as possible.

Baseline Review

The first step in considering possible equipment modifications and process changes for pollution prevention is to perform a baseline review of the environmental aspects of the product system. Before undertaking this review, it is necessary to define the system boundary to be considered. In most instances the system boundary will, at a minimum, encompass the manufacturing stage.

Kraft Canada uses steam for pre-cooking and a natural gas fuelled steam boiler for heating. Following an energy audit, Kraft developed a system to recover heat from the hot and humid process exhausts using a condensing heat recovery unit. An identical system was installed on a natural gas boiler exhaust to recover heat for use in plant space heating. These changes resulted in annual savings of over $250,000 and a 15% reduction in boiler plant and process air emissions. The payback period for the initial investment of $1.5 million was 4.5 years.

Source: From the experience of Jacques Whitford Environment Ltd.

A baseline review may be relatively simple, in which case basic process and material flow diagrams are often sufficient. However, if the initial analysis suggests modifications to major pieces of equipment, or changes to substantial aspects of a process within a facility or company-wide, then the review will likely be longer and more complex.

All reviews (regardless of their size) follow a sequence similar to that described in the section "How to Prepare a Pollution Prevention Plan" and in Appendix B, "Key Elements of a Baseline Review," including:

- Perform a thorough evaluation of all material flow inputs and outputs in the system (for example, the input for a water audit could often be determined from a water bill, while the outputs could be determined from meters, applicable records, employee interviews, and evaluation and estimation of the process(es) and employee/public use of the facility's water).
- Gather data and estimate amounts for the input and output streams.
- Refine any estimates so that the sum of all inputs equals the sum of all outputs.
- Determine the large consumers of materials, energy, water, etc.

Option Selection

Once the baseline review has been completed, a series of equipment modification or process change options should be developed. In most cases, the selection of options will be dictated largely by the economic impact of the change, and therefore all hidden costs should be considered and revisited while planning for implementation. Other cost areas that should be considered in the overall comparison of the options include:

- site preparation;
- installation and testing;
- employee training;
- operation of new equipment/procedures;
- tracking of employee acceptance, and of economic and environmental benefits;

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Over-filling of storage vessels often leads to spills of hazardous materials and expensive clean-up. After this problem was reviewed at a federal heating plant facility, a fillpipe cabinet was purchased and installed. This device has an alarm whistle, an overflow alarm light and a locking mechanism that a plant employee must unlock and supervise during refuelling. Costing only $2,000, this simple modification ensures that correct fuelling procedures are followed and protects against costly and environmentally damaging spills.

Source: www.on.ec.gc.ca/epb/fpd/en/epw/epsw04.html

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- site preparation;
- installation and testing;
- employee training;
- operation of new equipment/procedures;
- tracking of employee acceptance, and of economic and environmental benefits;

- waste handling and treatment costs; disposal fees;
- revision/modification of any outstanding issues; and
- regular maintenance.

Employee Involvement and Training

It is important to solicit comments prior to and upon completion of the implementation of any equipment modifications and process changes. Employee training should also be provided, where needed. This can introduce valuable new insights and ideas, and ensure a high level of acceptance and speed of implementation, saving time and money if modifications need to be performed.

Monitoring

As with other prevention practices, equipment modifications or process changes require specific performance indicators to enable the company to monitor the implementation and progress of these changes. These indicators should link back to the initial inventory of inputs and outputs. However, since other activities may also have been implemented, there will be a need for indicators specific to the equipment or process change. This can be accomplished by scaling down the boundaries of the materials flow analysis to that piece of equipment, keeping in mind that this flow data should also be collected prior to the equipment or process changes made. Progress should be reviewed regularly to examine the root cause of any deviations from the action plan or failure to achieve targets or milestones and to determine what corrective action, if any, should be taken. All employees should receive regular progress reports to reinforce the importance of their efforts.

References and Resources

For more information on pollution prevention and pollution prevention planning:

Canadian Pollution Prevention Information Clearinghouse: www.ec.gc.ca/cppic

Canadian Centre for Pollution Prevention: www.c2p2online.com

Canadian Environmental Protection Act, 1999: www.ec.gc.ca/CEPARegistry

Your Environment Canada Regional Office.

For more information on equipment modifications and process changes for pollution prevention:

Environment Canada, Ontario Region, Federal Programs Division, Environmental Protection Branch, Pollution Prevention Fact Sheet: www.on.ec.gc.ca/pollution/fpd/fsheets/intro-e.html

Freeman, Harry. 1995. *Industrial Pollution Prevention Handbook*. McGraw-Hill

Higgins, Thomas E. 1995. *Pollution Prevention Handbook*. CRC Press Inc.

Checklist for Equipment Modifications and Process Changes

Task	Responsibility	Completion Date
Assign overall responsibility for equipment modifications and process changes to a management representative		
Establish a cross-functional team		
Map out material flows and process steps		
For each process step, identify: • what happens, including cleaning and maintenance • type, quantity and cost of inputs • material and energy losses and waste generated • how each non-product output is disposed of and disposal costs		
Identify, evaluate and, where appropriate, select equipment modifications and process changes: • assess impacts on all aspects of the operation • account for pollution that may result from decommissioning equipment or moving materials as a result of proposed changes		
Establish performance targets		
Develop implementation plan		
Provide staff training		
Develop performance indicators to measure the success of specific measures and monitor progress toward targets		
Establish a formal review mechanism to: • evaluate the success of measures taken • identify new measures • provide feedback from the review to all employees		

Appendix F: Materials and Feedstock Substitution

Introduction

This information sheet describes the important contribution materials and feedstock substitution can make to pollution prevention. It reviews key steps for implementing this practice, presents examples illustrating how materials substitution has benefited various organizations and provides a checklist for supporting its implementation.

Pollution prevention is "the use of processes, practices, materials, products, substances or energy that avoid or minimize the creation of pollutants and waste, and reduce the overall risk to the environment and human health" (*Canadian Environmental Protection Act, 1999*). Pollution prevention is at the top of a hierarchy of environmental protection methods that also include off-site reuse and recycling, pollution control or treatment, disposal/destruction, remediation and clean-up. While all environmental protection methods provide some benefits, pollution prevention can provide the most cost-effective opportunities for reducing environmental and health risks while improving a business's bottom line.

Materials and feedstock substitution entails replacing polluting materials used in the production process or embedded within a product with non-polluting or less polluting materials and feedstock. Materials substitution aims to decrease or eliminate the quantity of toxic, hazardous or polluting materials used, thereby lowering the risks of harmful exposures to workers, consumers, communities and the environment.

Materials substitution can have both upstream and downstream benefits. The amendments to the *Clean Air Act* in the United States in 1990 called for reductions in volatile organic compounds (VOCs). Printing ink manufacturers fell under these new guidelines because petroleum-based inks contain 30% to 35% VOCs. This has resulted in a growing trend to use soybean oil based inks. These inks range from 2% to 5% VOCs and tend to perform better than petroleum inks, resulting in brighter colours and producing more impressions than the same amount of petroleum ink. Soy inks can also be removed from paper more easily, requiring less harsh chemicals in the recycling process.

There are different types of substitution approaches:

- **Feedstock substitutions** use an alternative feedstock to produce a substance. Although this substitution will not reduce the pollution created during the manufacturing or disposal stages, it can reduce the pollution from preparing the feedstock. For example, raising crops and converting them into fuel may create less pollution than that generated by extracting and processing crude oil into petrochemicals.
- **Product substitution**, by comparison, replaces an entire product with a less polluting one. New plastics made of starch that decomposes completely in water and compost piles can significantly reduce problems associated with petroleum-based plastics, for example.

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- **Product substitution**, by comparison, replaces an entire product with a less polluting one. New plastics made of starch that decomposes completely in water and compost piles can significantly reduce problems associated with petroleum-based plastics, for example.

An automotive company, Textron, based in Port Hope, Ontario, replaced the use of methylene chloride and realized a 68% reduction of VOCs over five years. This resulted in cost savings of approximately $400,000 per year from not purchasing the chemical, and $124,000 to $300,000 per year from not disposing of the hazardous materials.

Source: www.ec.gc.ca/pp/en/storyoutput.cfm?storyID=62

Opportunities for the application of materials substitution are broad and can include painting applications, parts cleaning, metal finishing, printing operations, building and grounds maintenance.

In some cases, regulatory pressures are the impetus to develop and use new materials and feedstock. In many cases, however, material and feedstock substitution can be justified on economic grounds. The elimination of toxic substances and other hazardous materials can significantly reduce the costs involved in their use, handling and disposal. These costs can include:

- engineering controls to minimize releases;
- regulatory reporting requirements;
- worker training;
- storage requirements; and
- disposal restrictions.

Other benefits can include improved worker health and safety. For example, a Chrysler Canada facility achieved a 10% reduction in lost time due to medical treatment injuries or other incidents when it changed from glue containing organic solvents to water-based glue.

Identifying Opportunities for Materials Substitution

Establishing Responsibility

There should be a manager responsible for supervising any materials substitution decisions and actions. In addition, a cross-functional team of people using and handling the materials in question is critical to effectively evaluating the benefit of materials and feedstock substitution. Involving individuals who play a role at different stages of the production process brings unique insight to the potential for pollution prevention throughout the life cycle of the material. In some cases, it may also be appropriate to involve specific suppliers.

Baseline Review

The materials substitution team should:

- identify and inventory products containing hazardous materials used within the facility;
- identify specific processes that use the hazardous materials and/or generate hazardous waste; and
- identify and inventory emissions, effluents and hazardous waste streams at the facility.

This information will help establish a material flow profile for the organization, and will assist in the establishment of objectives and targets. This review is similar to reviews required for other pollution prevention practices and, ideally, should be combined with them.[1]

Sources to collect the above information can include:

- product composition sheets;
- material safety data sheets (MSDS);[2]
- inventory records;
- data logs;
- production schedules;

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[1] For more information on conducting a baseline review to identify pollution prevention opportunities, please refer to Appendix B, "Key Elements of a Baseline Review."

[2] MSDS provide detailed information about the physical properties, toxicity, personnel protection required, and other safety precautions and waste disposal needs for specific materials. Contact the manufacturer of the material to obtain an MSDS.

- waste manifest documents; and
- environmental audit results.

Life Cycle Assessment

Life cycle assessment (LCA) is a tool to evaluate the environmental consequences of a product or activity across its entire life. Although the pollutants and wastes from the use and release of substances are often the focus of pollution prevention, in some cases more pollution can result from the extraction and conversion stages of actually "making" the polluting substance in question. LCA can help evaluate options to ensure that materials substitution does not just shift environmental and financial impacts to another stage along the life cycle. For example, switching to an aqueous-based solvent may decrease toxic emissions, but such a switch must also be evaluated to determine whether the new system increases overall energy use (and the associated releases from power generation), or results in other types of releases during manufacture, etc.

Planning

Setting Objectives and Targets

Once the material flows are determined, the team should set objectives and targets prioritizing action on inputs and waste streams.

Objectives are the overall goals the organization sets with regard to pollution prevention, and targets are the specific, measurable, achievable, time-bound performance requirements it sets to achieve its objectives. An example of an objective could be to reduce or eliminate the use of an input or the release of a particular pollutant, and the target could be achieving a 30% reduction compared to the previous year.

Identification of Substitutes

Based on the objectives and targets, the materials substitution team will then need to identify applications in which toxic or polluting materials can be substituted with alternatives that are environmentally benign or less hazardous.

Iogen Corporation, in co-operation with Petro-Canada, is developing and demonstrating a cost-effective process for the production of ethanol from biomass. Using a micro-organism's enzymes as the starting point, the process will turn straw, grasses, corncobs and corn stalks into a clean-burning ethanol fuel. With Iogen's technology, every litre of ethanol substituted for gasoline will reduce carbon dioxide emissions by more than 90% compared to gasoline. Blending 10% ethanol into all of Canada's gasoline by 2010 would result in a decrease of 10 megatonnes of carbon dioxide emissions per year. In addition to the environmental benefits, biomass-based ethanol provides farmers with an opportunity to turn residual material into a cash crop.

Source: www.ec.gc.ca/pp/en/storyoutput.cfm?storyID=6

Finding the correct substitute requires a thorough study of the available alternatives. Investigate a number of alternatives by contacting different suppliers and other businesses, in order to determine what is best suited to the specific application. For example, if an organization is trying to identify a substitute for an undesirable cleaning solvent currently in use, the following types of questions need to be asked:

- Why is cleaning necessary?
- What is the soil?
- How much soil can be tolerated?
- Can prior processes be changed to prevent soiling?
- Can subsequent processes be changed to tolerate soil?

When a substitute is identified, other questions need to be asked:

- Is the substitute regulated?
- Is it subject to any significant non-regulatory toxics reduction or pollution prevention (P2) program?
- Is it of concern to any customers?

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Other benefits can include improved worker health and safety. For example, a Chrysler Canada facility achieved a 10% reduction in lost time due to medical treatment injuries or other incidents when it changed from glue containing organic solvents to water-based glue.

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Identification of Substitutes

Based on the objectives and targets, the materials substitution team will then need to identify applications in which toxic or polluting materials can be substituted with alternatives that are environmentally benign or less hazardous.

Iogen Corporation, in co-operation with Petro-Canada, is developing and demonstrating a cost-effective process for the production of ethanol from biomass. Using a micro-organism's enzymes as the starting point, the process will turn straw, grasses, corncobs and corn stalks into a clean-burning ethanol fuel. With Iogen's technology, every litre of ethanol substituted for gasoline will reduce carbon dioxide emissions by more than 90% compared to gasoline. Blending 10% ethanol into all of Canada's gasoline by 2010 would result in a decrease of 10 megatonnes of carbon dioxide emissions per year. In addition to the environmental benefits, biomass-based ethanol provides farmers with an opportunity to turn residual material into a cash crop.

Source: www.ec.gc.ca/pp/en/storyoutput.cfm?storyID=6

Finding the correct substitute requires a thorough study of the available alternatives. Investigate a number of alternatives by contacting different suppliers and other businesses, in order to determine what is best suited to the specific application. For example, if an organization is trying to identify a substitute for an undesirable cleaning solvent currently in use, the following types of questions need to be asked:

- Why is cleaning necessary?
- What is the soil?
- How much soil can be tolerated?
- Can prior processes be changed to prevent soiling?
- Can subsequent processes be changed to tolerate soil?

When a substitute is identified, other questions need to be asked:

- Is the substitute regulated?
- Is it subject to any significant non-regulatory toxics reduction or pollution prevention (P2) program?
- Is it of concern to any customers?

- Does it require special disposal as a hazardous waste?

Evaluation

Various criteria can be used to compare options. Example criteria include:

- Waste reduction potential
- Reduction in toxicity
- Space requirements
- Employee health and safety
- Modifications of processes
- Cost
- Impact on operations
- Community acceptance
- Human resource
- Consistency with requirements other environmental programs
- Permit requirements
- Proven techniques

Testing

Based on a careful review of the collected information, the team will make recommendations on which substitutions to test. In accordance with basic procedures in most companies, testing is essential to ensure that any materials substitution does not cause more serious problems. A test procedure will need to be developed and performed on the substitution being considered. The results of the test will then have to be evaluated and statistically analyzed.

Supply Chain Management

One of the key barriers to materials and feedstock substitution is the tendency of many companies to use product specifications that dictate certain materials regardless of their environmental impacts. Organizations can attempt to overcome this barrier by working closely with suppliers and customers and communicating the organization's commitment to pollution prevention.

Involving and Training Staff

Staff may require training in the use and handling of new materials or feedstock. Standard operating procedures may also need to be updated, documented and distributed to the appropriate employees. Staff should be consulted on the reason for the change. Providing employees with the logic behind P2 changes encourages their positive involvement in the process of continual improvement. Many organizations establish incentive programs to encourage staff to develop the means to prevent hazardous and toxic emissions, and reduce costs.

Monitoring

Verifiable, reproducible and cost-effective environmental performance indicators should be established by the team and used to measure continual improvement. All material substitutions should be measured, and performance monitored against the organization's requirements and targets. The results obtained through monitoring programs can then be used to determine areas where improvement or corrective action may be needed.

Evaluation and Review

It is important that a periodic review by senior management take place to address whether the material substitution is effective and established targets are being met. There may be a need for changes in light of monitoring results, changing circumstances, new techniques and the commitment to continual improvement.

Ford's Windsor Casting Plant is a major user of reclaimed metals. It set objectives to reduce hazardous waste solvent, eliminate health and safety problems related to skin irritation, and reduce corporate liability. Substances targeted included ethylbenzene, toluene, 1,1,1 trichloroethane and perchloroethylene, and a 50% reduction of hazardous waste was set as a target. A project team from engineering and maintenance tested non-hazardous alternatives for six months and oversaw a transition to new cleaning solvents. By establishing a monitoring program, the plant was able to reduce its hazardous waste stream by more than 50%. This reduction also alleviated administrative and regulatory problems the plant was having with tracking and filing waste manifests. It improved health and safety conditions, eliminated hazardous waste disposal charges and minimized potential liabilities.

Source: Fourth Progress Report of the Canadian Vehicle Manufacturers' Association Pollution Prevention Project, June 1996

References and Resources

For more information on pollution prevention and pollution prevention planning:

Canadian Pollution Prevention Information Clearinghouse: www.ec.gc.ca/cppic

Canadian Centre for Pollution Prevention: www.c2p2online.com

Canadian Environmental Protection Act, 1999: www.ec.gc.ca/CEPARegistry

Your Environment Canada Regional Office.

For more information on materials and feedstock substitution:

The Solvent Alternatives Guide (SAGE): SAGE is a tool that can be help the selection of surface cleaning alternatives. Designed to serve as an electronic handbook that identifies the most viable alternative for a given scenario, SAGE is easy to use and does not require a detailed knowledge of process chemistry or mechanics. SAGE is available through the Control Technology Center in the United States. Further information can be obtained by calling the CTC Hotline at (919) 541-0800: clean.rti.org

The U.S. Environmental Protection Agency's Environmentally Preferable Purchasing Program hosts a website with useful guidance material, descriptions of analytical tools and links to other resources: www.epa.gov/opptintr/epp/how-to.html

Carstensen, Michelle. 1997. *Biochemicals for the Printing Industry*. Institute for Local Self-Reliance. Washington, D.C.

Curran, Mary Ann. 1995. "Using LCA-Based Approaches to Evaluate Pollution Prevention." Environmental Progress, Vol. 14, No. 4, November 1995

Freeman, Harry M. 1995. *Industrial Pollution Prevention Handbook*. McGraw-Hill

Higgins, Thomas E. 1995. *Pollution Prevention Handbook*. CRC Press

Lowe, L., J. Warren, and S. Moran. 1997. *Discovering Industrial Ecology: An Executive Briefing and Sourcebook*. Batelle Press

Checklist for Materials and Feedstock Substitution

Task	Responsibility	Completion Date
Assign overall responsibility for materials and feedstock substitution to a management representative		
Establish a cross-functional team		
For each process step, identify: • what happens, including cleaning and maintenance • type, quantity and cost of inputs • material and energy losses and waste generated • how each non-product output is disposed of and disposal costs		
Identify applications in which less polluting inputs can be substituted		
Investigate alternatives		
Determine if legislative restrictions apply to the material substitutions being investigated		
Complete an evaluation of the pre-selected substitutions; account for life cycle inputs, cost, ease of use, availability of supply, etc.		
Test recommended substitutions		
Evaluate results of testing		
Select substitutions		
Develop implementation plan		
Train affected staff (such as receiving, inventory management) on new requirements		
Communicate new requirements to suppliers; maintain regular communication on environmental issues		
Develop performance indicators to measure the success of specific measures, and monitor progress toward targets		
Establish a formal review mechanism to: • evaluate the success of the measures taken • identify new measures • provide feedback from the review to all employees		

Appendix G: Operating Efficiencies and Training

Introduction

Enhancing operating efficiencies and ensuring a well-trained staff are important contributors to competitiveness and profitability. As such, they form a routine part of most companies' activities. This information sheet describes how to further enhance corporate objectives by integrating pollution prevention considerations into ongoing efforts to improve operating efficiency and into ongoing training practices.

Pollution prevention is "the use of processes, practices, materials, products, substances or energy that avoid or minimize the creation of pollutants and waste, and reduce the overall risk to the environment and human health" (*Canadian Environmental Protection Act, 1999*). Pollution prevention is at the top of a hierarchy of environmental protection methods that also include off-site reuse and recycling, pollution control or treatment, disposal/destruction, remediation and clean-up. While all environmental protection methods provide some benefits, pollution prevention can provide the most cost-effective opportunities for reducing environmental and health risks while improving a business's bottom line.

In many cases, improving operational efficiencies can be a very cost-effective way to prevent pollution and reduce costs or improve quality. These multiple objectives can often be achieved through basic improvements in work procedures, such as changing production schedules to minimize equipment and feedstock changeovers, improving maintenance scheduling, segregating by-products at source, and training and encouraging staff to improve material handling, implement good housekeeping practices and recognize pollution prevention opportunities. These practices often yield substantial benefits, including reduced raw material and waste disposal costs, less production down-time, and improved productivity.

Operating Efficiencies

Cost-effective opportunities to implement pollution prevention through improved operating efficiencies generally exist in both small and large industries. They are particularly applicable to manufacturing industries with significant water and solvent use or liquid and hazardous waste production.

The first step in identifying opportunities to enhance operating efficiencies is to conduct a careful review of all production processes. This review should include all aspects of the process, from raw materials delivery through each production step to final product storage. This review is similar to reviews required for other pollution prevention practices and, ideally, should be combined with them.[1]

Common operational efficiency techniques and actions can be grouped into five categories:

1. basic operations;
2. cleaning and maintenance;
3. materials and waste storage and handling;
4. process control; and
5. good housekeeping.

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[1] For more information on conducting a baseline review to identify pollution prevention opportunities, please refer to Appendix B, "Key Elements of a Baseline Review."

Many of the methods and techniques to promote pollution prevention through enhanced operational efficiencies are well known and inexpensive to implement, with little or no capital outlay required. For example, a producer of breaded foods implemented various simple measures, including dry clean-up, installation of drip trays under processing equipment and better systems for collecting and handling waste material. These changes resulted in:

- **[illegible] reduction in water usage for clean-up;**
- **elimination of solid wastes for landfill;**
- **almost [illegible] reduced organic load of wastewater; and**
- **increased revenues from the sale of waste solids to recovery firms.**

Source: [illegible]

Examples of each of these techniques are discussed below.

Basic Operations

Numerous improvements can often be made to basic operations to optimize raw material use, reduce waste and prevent pollution.

In general:

- Train employees about safe handling of materials and wastes.
- Write equipment procedures in plain language and post for quick reference.
- Close containers with tight-fitting lids and bungs to avoid evaporation and contamination.
- Use spigots and nozzles for bulk containers to prevent drips and spills.
- Have employees return empty containers before getting new ones.
- Use input materials for their intended use only.
- Use funnels for transferring wastes to storage containers.
- Reuse used absorbents to soak up puddles.

The Manitoba Heavy Construction Association's Environmental Program ([illegible]), launched in 1997, promotes and introduces sound environmental management techniques through its Environmental Practices Accreditation Program. [illegible] assists companies in implementing environmental management systems, best environmental management practices, materials management databases and emergency response plans. Results include fewer and less severe spills, and consequently fewer emissions. Better-trained and informed employees have also led to a safer workplace for the over [illegible] employees. In addition, the reduction in the number and severity of spills has resulted in financial savings in terms of clean-up costs and time lost to accidents.

Source: [illegible]

- Squeegee excess cleaning solutions from parts, drip pans, or floor before cleaning or applying an absorbent material.
- Moisten rags with a squeeze bottle instead of soaking rags in solvent.
- Collect recyclable or reusable liquids from shop rags.
- Collect shop rags and clean through a laundry service for reuse.
- Return empty containers to suppliers and accept empty containers from customers.
- Consider whether changes in the size and shape of containers will reduce waste generation or enhance waste collection efficiencies.

For equipment operation and production scheduling:

- Maximize batch size to reduce clean-out waste.
- Dedicate equipment to a single product.
- Check for empty containers, spill residues, leaking tanks, reactors, pipes, valves and hoses.

- Properly maintain and operate process equipment to prevent the production of off-specification products, excess or spent process materials and solution, unused additives, and catalysts.
- Check pipes for leaks at seams, pump seals, and flange gaskets.
- Install overflow alarms, rupture disks and relief valves.
- Use all welded piping construction, flange guards, double seals and bellows-sealed valves.
- Test containers periodically.
- Use secondary containment.

For chemical processes:

- Optimize chemical reactions by keeping the temperature at the proper level.
- Check temperature control devices routinely.
- Check mechanical agitators to ensure proper operation and mixing.
- Correctly adjust feed flow and purity controls.

According to the Atlantic Golf Superintendents' Association, improvements in maintenance and turf management can help golf courses reduce the areas treated with pesticides and fertilizers by 33% to 50%, as well as reduce pesticide and fertilizer rates.

Source: [illegible]

For metal parts cleaning, plating and surface treating:

- Reduce the use of solvent and water in cleaning.
- Replace solvent-based cleaners with aqueous cleaning solutions for reduced air emissions.
- Use greaseless or water-based binders to eliminate caustic cleaners for binder removal.
- Remove drag-out by placing all parts in racks and all cavities face down for rapid drainage.
- Allow enough time for parts to drain completely.
- Return collected drag-out to product solution tank.
- Avoid excessive rinsing and consider using fog rinsing to reduce rinse water use.
- Use countercurrent rinsing to recycle dilute solution.
- Prevent spillage by adding sideboards or splash guards.
- Prevent loss of volatile solutions and solvents by locating storage tanks away from sources of heat and by adding lids or chillers.

For stripping and painting:

- Replace solvents with abrasive media stripping (preferably recyclable) such as plastic beads, or use a water-based cleaning solution.
- Use water-based paints.
- Avoid overspray by holding the gun level, setting controls appropriately, and maintaining proper gun distance and speed.
- Isolate spray booths for solvent-based paints from those for water-based paints to prevent mixing.
- Emphasize quality control and pre-inspection to lower the rejection rate resulting from inadequate pre-cleaning.
- Schedule batches to maximize efficiency (e.g., avoid scheduling consecutive batches of products that react with one another; schedule batches of similarly coated products consecutively and schedule dark batches after light batches.

Cleaning and Maintenance

Properly and regularly done, cleaning and maintenance prevents and corrects sources of waste and pollution, reduces operating costs and enhances quality. Possible opportunities include:

- Allow time for proper drainage of equipment prior to cleaning.
- Create and use a master preventive maintenance schedule and repair history file.
- Schedule regular cleaning and maintenance to avoid product contamination, remove deposits, maintain process efficiency, extend equipment life, and allow for inspection and repair.
- Schedule jobs in batches to reduce the need for frequent cleaning.

Many of the methods and techniques to promote pollution prevention through enhanced operational efficiencies are well known and inexpensive to implement, with little or no capital outlay required. For example, a producer of breaded foods implemented various simple measures, including dry clean-up, installation of drip trays under processing equipment and better systems for collecting and handling waste material. These changes resulted in:

- **30% reduction in water usage for clean-up;**
- **elimination of solid wastes for landfills;**
- **almost 80% reduced organic load of wastewater; and**
- **increased revenues from the sale of waste solids to recovery firms.**

Source: Freeman, 1995

The Manitoba Heavy Construction Association's Environment Program (MEP), launched in 1997, promotes and introduces sound environmental management techniques though its Environmental Practices Accreditation Program. MEP assists companies in implementing environmental management systems, best environmental management practices, materials management databases and emergency response plans. Results include fewer and less severe spills, and consequently fewer emissions. Better-trained and informed employees have also led to a safer workplace for the over 100,000 employees. In addition, the reduction in the number and severity of spills has resulted in financial savings in terms of clean-up costs and time lost to accidents.

Source: www.ec.gc.ca/pp/en/storyoutput.cfm?storyID=8

Examples of each of these techniques are discussed below.

Basic Operations

Numerous improvements can often be made to basic operations to optimize raw material use, reduce waste and prevent pollution.

In general:

- Train employees about safe handling of materials and wastes.
- Write equipment procedures in plain language and post for quick reference.
- Close containers with tight-fitting lids and bungs to avoid evaporation and contamination.
- Use spigots and nozzles for bulk containers to prevent drips and spills.
- Have employees return empty containers before getting new ones.
- Use input materials for their intended use only.
- Use funnels for transferring wastes to storage containers.
- Reuse used absorbents to soak up puddles.
- Squeegee excess cleaning solutions from parts, drip pans, or floor before cleaning or applying an absorbent material.
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- Properly maintain and operate process equipment to prevent the production of off-specification products, excess or spent process materials and solution, unused additives, and catalysts.
- Check pipes for leaks at seams, pump seals, and flange gaskets.
- Install overflow alarms, rupture disks and relief valves.
- Use all welded piping construction, flange guards, double seals and bellows-sealed valves.
- Test containers periodically.
- Use secondary containment.

For chemical processes:

- Optimize chemical reactions by keeping the temperature at the proper level.
- Check temperature control devices routinely.
- Check mechanical agitators to ensure proper operation and mixing.
- Correctly adjust feed flow and purity controls.

According to the Atlantic Golf Superintendents' Association, improvements in maintenance and turf management can help golf courses reduce the areas treated with pesticides and fertilizers by 33% to 50%, as well as reduce pesticide and fertilizer costs.

Source: www.ec.gc.ca/pp/en/storyoutput.cfm?storyID=20

For metal parts cleaning, plating and surface treating:

- Reduce the use of solvent and water in cleaning.
- Replace solvent-based cleaners with aqueous cleaning solutions for reduced air emissions.
- Use greaseless or water-based binders to eliminate caustic cleaners for binder removal.
- Remove drag-out by placing all parts in racks and all cavities face down for rapid drainage.
- Allow enough time for parts to drain completely.
- Return collected drag-out to product solution tank.
- Avoid excessive rinsing and consider using fog rinsing to reduce rinse water use.
- Use countercurrent rinsing to recycle dilute solution.
- Prevent spillage by adding sideboards or splash guards.
- Prevent loss of volatile solutions and solvents by locating storage tanks away from sources of heat and by adding lids or chillers.

For stripping and painting:

- Replace solvents with abrasive media stripping (preferably recyclable) such as plastic beads, or use a water-based cleaning solution.
- Use water-based paints.
- Avoid overspray by holding the gun level, setting controls appropriately, and maintaining proper gun distance and speed.
- Isolate spray booths for solvent-based paints from those for water-based paints to prevent mixing.
- Emphasize quality control and pre-inspection to lower the rejection rate resulting from inadequate pre-cleaning.
- Schedule batches to maximize efficiency (e.g., avoid scheduling consecutive batches of products that react with one another; schedule batches of similarly coated products consecutively and schedule dark batches after light batches.

Cleaning and Maintenance

Properly and regularly done, cleaning and maintenance prevents and corrects sources of waste and pollution, reduces operating costs and enhances quality. Possible opportunities include:

- Allow time for proper drainage of equipment prior to cleaning.
- Create and use a master preventive maintenance schedule and repair history file.
- Schedule regular cleaning and maintenance to avoid product contamination, remove deposits, maintain process efficiency, extend equipment life, and allow for inspection and repair.
- Schedule jobs in batches to reduce the need for frequent cleaning.

- Use high-pressure spray nozzles for tank rinsing.
- Visually inspect for leaks and damage to all processes and storage tanks, including all equipment attached to them, at least once a month.
- Monitor and test all discharges from internal heating and cooling coils quarterly.
- Regularly calibrate and adjust all automatic process control devices to increase productivity and prevent loss.

Materials and Waste Storage and Handling

Examples of materials and waste storage and handling actions that can help reduce waste and prevent pollution include:

- Store materials in areas and conditions to preserve shelf life.
- Use large enough tanks and containers to minimize overflows.
- Use funnels for filling.
- Keep materials covered to avoid loss and contamination.
- Store materials on pallets for easy detection and response to leaks.
- Label and store wastes according to regulation.
- Isolate waste streams by toxicity, type of contaminant, or physical form to reduce disposal, handling and/or transport costs (consider setting up staffed collection centres to prevent unauthorized mixing of wastes).
- Prevent hazardous waste from contaminating non-hazardous materials by keeping them from coming into contact with each other.
- If possible, avoid underground storage tanks.
- Store hazardous wastes where spills will not contaminate sewers and streams and away from major traffic areas.
- Provide secondary containment for fluid storage.
- Have emergency equipment ready for spills and leaks, train employees to use emergency equipment, and practise use.
- Label hazardous waste at its source while it can still be easily identified.
- In paint operations, separate clean-up toluene according to colour and type of ink cleaned, and then filter and reuse the collected wastes to thin future batches of the same ink.
- In metal-working operations, filter aluminum particles from soluble oils to reclaim the aluminum and reuse the oil.

Process Control

Process control, or the manner in which a production system's reliability and performance are ensured, is crucial to operating efficiency and will already be a central focus for most manufacturers. In many cases, improvements in process control can also help prevent pollution. The optimization of production or process control systems requires detailed assessment of process dynamics. For simplicity, process control opportunities can be divided into such categories as:

- reduction of waste generation through process efficiency improvements;
- pre-treatment of pollution-containing effluents using chemical reactions;
- capture and recycling of pollutant-containing waste by-products; and
- collection and storage of pollutant-containing waste by-products.

The introduction of self-tuning controllers that adapt to the dynamic characteristics of a process and automatically select their tuning parameters is an example of the application of process control innovations to improve process efficiency. The integration of fuzzy logic controllers – equipment that exploits system inaccuracies – is another cost-effective technique by which process efficiency can be optimized (particularly in complex production systems) while also helping reduce energy use and prevent pollution. Finally, statistical process control uses statistical data to determine the optimal control conditions of a system. Through the implementation of discrete process adjustments, and observation of the results over time, both baseline conditions and improvements in system efficiency can be charted and tracked over a given period of operation.

Good Housekeeping

Good housekeeping involves day-to-day care and actions that all employees can take, including:

- Keep storage and work areas clean and well organized, and containers properly labelled.
- Use drip pans and splash guards.
- Track spill occurrences to ensure clean-up and corrective action.
- Use absorbents for minor spills and leaks.

Training and Involving Employees

The techniques described in this information sheet will be effective only if employees are trained and motivated to apply them in their day-to-day work. Many of these techniques require co-ordination and co-operation of employees at various points in the overall operation of the facility, including people in planning, procurement, production, engineering, environmental affairs, maintenance, and so on. As many of these people as possible should be involved in the training and in the ongoing search for operational efficiencies.

Good training will give employees the knowledge and skills they need to find and practise operating efficiencies, but to be successful, training must be linked to and foster enhanced employee involvement. Employees have the power either to limit the success of pollution prevention initiatives or to advance it beyond expectations.

In 1999, Metrographic Printing of Nova Scotia printed a "mini environmental report" on the back of their Christmas card. They included information on both the environmental and financial benefits realized from their waste and water reduction initiatives. This informed staff, suppliers and customers of their priorities and results.

Source:www.cleanprint.org/regional/atlantic/success

Some of the steps a company should consider taking to help motivate employees to support pollution prevention include:

Convey upper management's commitment to employees through a formal policy statement or management directive. A policy statement needs to address why a pollution prevention practice is important to the company, what is to be accomplished in qualitative terms, and who will do it.

Understand your corporate and plant cultures and design your pollution prevention plan and activities to work within those cultures. Is your company quality-driven, management-driven or "champion"-driven? Are grassroots-type efforts effective? Do slogans and logos motivate or are they seen as gimmicky?

At James Maclaren Industries (pulp and paper) in Quebec, environmental training emphasizes preventive actions, the relationship between the company and the environment, principles of reasoned due diligence and adherence to rules and regulations. Improved waste management has resulted in savings of $400,000 a year at one plant and more than $90,000 a year at another.

Source: www.ec.gc.ca/pp/en/storyoutput.cfm?storyID=45

be charted and tracked over a given period of operation.

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- Use drip pans and splash guards.
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Source: www.ec.gc.ca/pp/en/storyoutput.cfm?storyID=45

Involve employees in pollution prevention planning, implementation and evaluation. They can participate through quality circles, task forces, suggestion programs or a combination of these.

Educate employees, both new and veteran, about the plan's goals and their pollution prevention responsibilities under the plan. Provide the necessary training so that employees can fulfil these responsibilities.

Inform employees of progress. Posting program achievements will demonstrate to employees that their efforts are making a difference.

Recognize employees' efforts. Immediate recognition of early accomplishments helps establish support for pollution prevention. Recognition programs sponsored by upper management help sustain employee motivation.

Motivate employees through additional incentives, such as bonuses, or non-monetary recognition such as awards or plaques.

Publicize success stories, both internally and externally. Find ways to make everyone aware of your successes, including employees, their families, stockholders, regulators and the community.

References and Resources

For more information on pollution prevention and pollution prevention planning:

Canadian Pollution Prevention Information Clearinghouse: www.ec.gc.ca/cppic

Canadian Centre for Pollution Prevention: www.c2p2online.com

Canadian Environmental Protection Act, 1999: www.ec.gc.ca/CEPARegistry

Your Environment Canada Regional Office.

For more information on operating efficiencies and training:

Freeman, Harry M. 1995. *Industrial Pollution Prevention Handbook*. McGraw-Hill

Higgins, Thomas E. 1995. *Pollution Prevention Handbook*. CRC Press Inc.

Ohio Environmental Protection Agency, Fact Sheet Number 22, September 1994, "Enhancing Employee Involvement in Pollution Prevention Activities": www.epa.state.oh.us/opp/fact22.txt

Virginia Department of Environmental Quality, Pollution Prevention Workplace Fact Sheet, "Pollution Prevention in the Workplace": www.deq.state.va.us/p2/factsheets/work.html

University of Nebraska at Lincoln, Cooperative Extension, Pollution Solutions, Waste Reduction Assistance for Business, "Common P2 Methods": outreach.missouri.edu/polsol/p2meth.htm

U.S. Environmental Protection Agency and Alternative Technology Division, California Department of Toxic Substances Control. "Waste Minimization for Hazardous Materials Inspectors: Module 1": p2.utep.edu/publications/manual1.cfm

Checklist for Operational Efficiencies and Training

Task	Responsibility	Completion Date
Assign overall responsibility for operational efficiencies and training to a management representative		
Establish a cross-functional team		
Map out material flows and process steps		
Complete an inventory of raw materials and inputs; identify type of material or input, use, annual quantity, cost and suppliers		
For each process step, identify: • what happens, including cleaning and maintenance • type, quantity and cost of inputs • material and energy losses and waste generated • how each non-product output is disposed of and disposal costs		
Overall and for each process step, identify, evaluate and, where appropriate, select operating efficiency opportunities in the areas of, for example: Basic operations general equipment operations and production scheduling chemical processes parts cleaning, plating and surface treatment stripping and painting Cleaning and maintenance Materials and waste storage Good housekeeping		
Establish performance targets		
Develop an implementation plan		
Provide staff training		
Develop performance indicators to measure the success of specific measures and monitor progress toward targets		
Establish a formal review mechanism to: • evaluate the success of measures taken • identify new measures • provide feedback from the review to all employees		

Appendix H: Purchasing Techniques and Inventory Management

Introduction

Pollution prevention is "the use of processes, practices, materials, products, substances or energy that avoid or minimize the creation of pollutants and waste, and reduce the overall risk to the environment and human health" (*Canadian Environmental Protection Act, 1999*). Pollution prevention is at the top of a hierarchy of environmental protection methods that also include off-site reuse and recycling, pollution control or treatment, disposal/destruction, remediation and clean-up. While all environmental protection methods provide some benefits, pollution prevention can provide the most cost-effective opportunities for reducing environmental and health risks while improving a business's bottom line.

This information sheet addresses two separate, yet related, pollution prevention practices: environmentally preferable purchasing and environmentally responsible inventory management:

- **Environmentally preferable purchasing** involves the integration of environmental considerations into existing purchasing practice. When making purchasing decisions, companies should consider the environmental features of the product or service alongside traditional factors such as product safety, price, performance and availability. By integrating environmental issues into the purchasing process, organizations can reduce material and energy consumption, avoid the unnecessary use of toxic substances in their products, minimize waste generation and, in many cases, reduce costs.
- **Environmentally responsible inventory management** entails the incorporation of environmental considerations into existing inventory management systems. This practice can significantly reduce waste associated with expired, damaged and unused product and packaging, and save money.

Environmentally preferable purchasing and inventory management techniques are most applicable in organizations that purchase significant quantities of products or services, and that manage an on-site inventory of products or component parts. Some of these techniques are discussed below.

Environmentally Preferable Purchasing

Approaches and techniques available for "greening" purchasing can be grouped into six categories, described below. Since changing material inputs may affect product quality, performance and cost, and the availability of components, explicit value judgments and trade-offs may be required. These value judgments and trade-offs should be acknowledged and reviewed on a regular basis.

Tailoring Purchases to Specific Needs

There are many examples of companies saving time and money and avoiding or reducing waste generation by tailoring their purchases to meet specific needs. Such tailoring practices can include:

- **Minimizing the number of different products that serve the same function.** A careful review of purchase records often reveals multiple small-quantity purchases of products that serve similar or identical functions. For example, a company may be purchasing multiple brands and types of lubricants, when only one or two different types may meet all intended applications. Using this technique, automotive manufacturers have reduced the number of plastic resins they purchase, thereby reducing costs through bulk purchases and increasing the potential for further in-house recycling and end-of-life recycling. When reviewing the types of similar products used, consideration should also be given to the environmental properties of the products, giving preference to products with less and fewer environmental impacts. While an all-purpose chemical-based cleaner may meet all cleaning needs, a company may find that a more benign cleaner would work for 75% of cleaning needs. In this case, there is a trade-off to be made between universality (one cleaner for all purposes) and reducing the environmental – and potential health – impacts of the products selected.

- **Ordering appropriate sizes of materials to avoid off-cut waste**. During construction projects, significant quantities of waste (in the form of off-cuts) can be avoided by ordering materials pre-cut to the required dimensions. Similarly, materials purchased for use in any cutting operations, such as foam, textiles and metal, should be of a size that minimizes cutting waste. Also, small reductions in packaging material size or weight can yield significant savings. Once suppliers are aware of your specific requirements, they are often able to accommodate them, allowing the purchaser to save money through waste reduction.
- **Bulk purchasing**. Bulk purchasing can result in direct savings through economies of scale. It can also reduce packaging waste and increase the efficiency of delivery, since fewer trips are required to deliver the material. Organizations considering this option should consider the shelf life and the anticipated demand for the product to avoid generating additional waste in the form of expired or unused product. Only purchase appropriate quantities for projected use. If considering bulk purchase of chemicals, be aware that large-quantity chemical storage on-site can increase the risk and the potential impact of a spill.

Green Specifications

Increasingly, corporate and institutional consumers are incorporating environmental specifications into their product and packaging specifications. These specifications can relate to a wide range of attributes, including product or packaging content, labelling, design features, reusability of the product and take-back of off-spec or spent product.

Many organizations begin efforts in this area by focusing on one environmental attribute. The attribute may be chosen for a number of reasons, such as:

- Regulatory pressures. In the face of an impending ban on the manufacture and import of CFCs, many organizations required their suppliers to provide CFC-free refrigerants and degreasers in the mid-1990s.
- Market pressures. In 1999, a number of companies, including Home Depot and IKEA, announced they would phase out purchases of old-growth wood. These decisions responded in part to intensive advocacy campaigns.
- Heightened awareness of employees and consumers. Throughout the 1980s and 1990s, consumer demand for reduced and recyclable packaging induced many companies to reduce the amount of packaging they used and to set minimum recycled content percentages for their packaging.

Various companies, governments and other institutions have developed more comprehensive environmental specifications to address multiple environmental attributes of the products they purchase. The principal challenge faced in such an approach is the difficulty of obtaining verifiable information on environmental impacts across the full life cycle of certain products; for many products, this information is not available. Companies have addressed this limitation in different ways:

1. They may rely on environmental labelling programs to assess independently the environmental performance of a product across its life cycle and authorize companies whose products meet a product-specific standard to display an environmental label. In Canada, the "EcoLogo" symbol is used to indicate that a product has met the guidelines of the Environmental Choice Program, Canada's environmental labelling program.
2. Some companies require their purchasers to maximize one or more of several environmental attributes. This type of guidance provides employees with direction on what attributes to consider, and provides them with flexibility when applying these criteria to different products.
3. Other companies have developed their own systems for evaluating the potential environmental impacts of the product and, in some cases, the product's manufacturing process. Canon has developed and published *Green Procurement Standards* and the *Green Procurement Standards Guidebook*. These publications present an index for rating a large number of product-specific parameters as well as the corporate environmental structure of suppliers.

The City of Santa Monica, California, transformed its purchasing practices to promote environmentally friendly products without compromising performance standards or budgetary requirements. As a result, Santa Monica has reduced its annual use of chemicals considered to be hazardous or toxic by 3,200 pounds (1,440 kg). Environmental purchasing techniques led to reductions in the use of toxic cleaning products, pesticides and virgin motor oil, as well as an increase in the use of less-polluting alternative fuels and recycled products. Economically, the City of Santa Monica saved 25% in motor oil costs and an additional 30% in pest management costs, while simultaneously creating a more clean and healthy environment.

Source: www.epa.gov/opptintr/epp/pdfs/santa.pdf

Prohibiting or Limiting Certain Substances

Increasingly, it is common to see organizations prohibit the use of specific substances in materials they purchase. Some of these prohibitions are enacted to ensure regulatory compliance. For example, when Germany passed a law in 1995 forbidding the use of certain azo-dyestuffs (colouring agents) in consumer products that come into contact with the skin, clothing manufacturers responded by requiring their suppliers to certify the materials they supplied were "azo-free." A number of companies have taken this concept one step further, and have screened the chemical substances they use against a wide range of criteria. Based on this screening, they often identify a black list and a grey list of substances. The black list identifies substances that employees are prohibited from purchasing and which cannot be contained in materials purchased by the company. The grey list identifies substances the company plans on phasing out once it identifies more environmentally benign substitutes. While decisions regarding which chemicals to prohibit or phase out usually involve many departments, including R&D, product managers, industrial engineering, and environment, health and safety professionals, it is usually the purchasing department's responsibility to implement the policy and communicate the information to suppliers.

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List of Approved Products

Some companies have created a list of "approved" products with particular environmental attributes. Although somewhat inflexible, this technique can simplify the purchasing process, since it does not require individual employees to make judgments on the environmental preferability of different products.

Qualifying Suppliers

Some companies require potential suppliers to "pre-qualify." For example, they may require suppliers to have a corporate environmental policy in place, or to abide by specific industry codes of conduct (such as Responsible Care® in the chemical sector), or be certified according to national or international environmental standards (such as ISO 14001). These requirements are often a component of the corporate environmental risk management program.

Working Collaboratively with Suppliers

In recent years, there has been a trend toward more collaborative efforts between companies and their suppliers. This trend is particularly evident in the move toward just-in-time delivery. Increasingly, companies are working closely with their suppliers on environmental issues. This type of collaboration can take many forms, such as:

- developing a program to return off-spec products and/or scrap materials to the supplier for reuse or recycling;
- using reusable transport packaging for delivery of components;
- involving the suppliers in joint R&D programs;
- creating partnerships related to disassembly;
- enhancing the service component of the relationship, where the supplier retains ownership and responsibility for certain pieces of equipment (e.g., parts washers); and
- provision of training and information to suppliers to help enhance their environmental management capacities.

A number of companies have changed the nature of their relationship with their chemical suppliers to a more service-focused relationship. The chemical suppliers work on-site, and become responsible for such tasks as chemical purchasing, tracking the on-site inventory to ensure proper inventory levels are maintained, operating the material safety data sheets (MSDS) program, and collecting data required for environmental reports. Under some arrangements, the suppliers are offered financial incentives, such as sharing in the cost savings from reduced chemical purchases, to decrease the amount of chemicals sold. In this type of model, suppliers are paid for providing and managing chemicals, so their profit is based on providing a high-quality service, not on selling more chemicals. Benefits of this approach include a reduction in purchase of unneeded chemicals, decreased costs to dispose of outdated overstock, and reduction of the risk associated with a larger, more diverse chemical inventory. More information on such arrangements is available through the Chemical Strategies Partnership: www.chemicalstrategies.org

Environmentally Responsible Inventory Management

All organizations have some form of inventory management system in place. Incorporating environmental considerations into existing inventory management procedures can reduce the amount of waste generated from expired, unused and damaged product. In many instances, environmental considerations also reinforce sound health and safety practices, including the use of current Material Safety data sheets[1] and Workplace Hazardous Materials Information System labelling.

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[1] MSDSs provide detailed information about the physical properties, toxicity, personnel protection requirements, and other safety precautions and waste disposal needs for specific materials. Contact the manufacturer of the material to obtain an MSDSs.

Several inventory management techniques are described below.

Managing Materials Demand

The first step in applying a preventive approach to inventory management is that of *managing materials demand*, a process that provides a holistic understanding of a company's materials requirements.

Managing materials demand involves six steps:

1. Forecast production and other activities based upon operational schedules and well-grounded assumptions.
2. Divide each activity into identifiable tasks.
3. Evaluate each task with a view to determining the materials requirements, use levels and rates of consumption.
4. Combine materials requirements from individual tasks and activities in an effort to determine overall operational requirements.
5. Determine the required restocking rates for the operations at hand, based upon manufacture and transportation rates.
6. And, finally, identify the central supply required in order to meet the operational demand.

In addition to purchasing costs, the costs of managing chemical products include those associated with inventory carrying, compliance (including record keeping and reporting), training, health and safety, emergency preparedness, and disposal of unused or expired chemicals. Based on discussions with several companies, the Chemical Strategies Partnership has seen chemical management costs range from US$1 to $10 for every dollar of chemical purchased. In other words, for a facility that purchases US$5 million in chemicals, additional costs of using these chemicals could be between US$5 million and US$50 million.

Source: www.chemicalstrategies.org/Service_Model.html

Inspection of Goods

Raw materials and other goods should be inspected carefully upon receipt so that damaged goods can be immediately returned to the supplier. Damaged goods unknowingly accepted into the inventory can cause a wide range of problems, including poor product quality and/or performance, loss of material through leaks and, in the case of certain chemical substances, potential risk to worker health and safety.

Identify Storage Requirements

Different materials have different storage requirements for such parameters as temperature, light, moisture and length of storage. Determining and respecting these requirements can reduce unnecessary waste and maintain input quality. Storage requirements should be identified and assessed for all materials, and procedures should be in place to ensure these storage conditions are met. Employee training on these requirements is another important practice.

Stock Rotation

Good stock rotation procedures can ensure that material is used on a first-in, first-out basis. This technique helps to prevent waste associated with expired materials. The inventory management system can be used to monitor the effectiveness of these procedures by tracking the expiry dates of the materials in storage.

Minimize Inventory and Implement Just-in-Time Delivery

A number of organizations have established minimum and maximum acceptable storage quantities for each chemical substance kept on site. By keeping on-site inventory of hazardous materials to the minimum level required to prevent disruption to production, companies are able to reduce the environmental risk associated with bulk chemical storage. Just in time delivery can also provide environmental benefits by reducing damage to materials during storage and movement around the site.

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Key Steps to Implementing Purchasing Techniques and Inventory Management

Establish Responsibility

Making these changes requires a "champion." Be sure to clearly assign overall responsibility for identifying and implementing environmental purchasing and inventory management techniques.

In addition, a team is essential for sharing information related to the use and handling of different products at each stage of the production process, and to involve all affected parties. The team should include a representative from each of the following areas: purchasing; research, design and development; shipping and receiving; industrial engineering; production; marketing; maintenance; and environment, health and safety. In some cases, it may also be appropriate to involve specific suppliers.

Baseline Review

The interdepartmental team should identify all inputs and outputs, including wastes. This review is similar to reviews required for other pollution prevention practices and, ideally, should be combined with them.[2] The team should then identify alternative inputs (e.g., by collecting information on green product certification programs). Based on this information, the team can determine the potential for:

- reducing the number of different products purchased in the same product category;
- substituting an environmentally benign or less harmful substance for an environmentally harmful product;
- reducing the amount of material stored on-site; and
- improving storage practices to reduce stock expiration and waste generation.

Based on a careful review of inputs and their potential environmental impacts, the interdepartmental team may also make recommendations on environmental criteria to be used in both material selection and vendor selection. These recommendations should be based on sound science, and be compatible with production and market requirements.

Establish Targets

Once the team understands the material flows and potential alternatives, it can establish specific, time-based, measurable performance targets. Such targets should be consistent with any broader objective or target established within the organization's environmental management system (EMS) or pollution prevention plan. For example, if an objective stated in the EMS is to reduce waste sent off-site for disposal by 20% by 2003 (using 2000 as the base year), then a specific target might be to reduce waste caused by stock expiration by a certain percentage within the same time period. In this instance, the organization might commit to a 20% reduction in expired stock as well or, if the team believes specific actions could lead to a larger reduction, it might exceed the overall objective and aim for a 75% reduction in expired stock.

Provide Training

Purchasing staff must be trained in any new requirements, including the rationale for the changes, and their role in implementing them. They should also have written materials summarizing the changes for future reference. Any changes to inventory management practices must also be clearly communicated to employees working in receiving and inventory management.

Communicate with Suppliers

Successful implementation of new purchasing and inventory management techniques requires

[2] For more information on conducting a baseline review to identify pollution prevention opportunities, please refer to Appendix B, "Key Elements of a Baseline Review."

co-operation from suppliers. Suppliers should be informed of overall environmental policies as well as any specific purchasing policies or programs. Communication with suppliers should be a two-way dialogue, since they may be able to offer a new perspective and draw on their expertise and experience with other customers to contribute to appropriate solutions.

Establish Performance Indicators

Specific performance indicators should be established to help monitor the implementation and success of purchasing and inventory management practices. While these indicators need to be tailored to the specific initiatives undertaken, they could include such measures as the volume of expired product discarded each month (to assess the impact improved inventory management practices are having), or the percentage of product (expressed in absolute numbers or in a dollar value) that meets specific environmental criteria defined by the company.

Review and Evaluate

On a regular basis, the organization should monitor and evaluate progress toward implementing specific action items and meeting established targets. The team should examine the root cause of any deviations from the action plan or failure to achieve targets or specific milestones and determine what corrective action, if any, should be implemented.

References and Resources

For more information on pollution prevention and pollution prevention planning:

Canadian Pollution Prevention Information Clearinghouse: www.ec.gc.ca/cppic

Canadian Centre for Pollution Prevention: www.c2p2online.com

Canadian Environmental Protection Act, 1999: www.ec.gc.ca/CEPARegistry

Your Environment Canada Regional Office.

For more information on environmentally preferable purchasing and inventory management tools and techniques, refer to:

Environmental Choice Program, Canada's national ecolabelling program: www.environmentalchoice.com

Note: TerraChoice Environmental Services, the administrators of the Environmental Choice Program, publish the *EcoBuyer Catalogue* of certified environmentally responsible products and services

U.S. Environmental Protection Agency. Environmentally Preferable Purchasing website: www.epa.gov/opptintr/epp

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Checklist for Purchasing Techniques and Inventory Management

Task	Responsibility	Completion Date
Assign overall responsibility for green purchasing and inventory management to a management representative		
Establish a cross-functional team		
Complete an inventory of raw materials and inputs; identify type of material or input, use, annual quantity, cost and supplier(s)		
Determine potential to reduce the number of different raw materials and inputs serving the same function		
Identify storage requirements for each category of raw material and input		
Identify current storage practices; determine need for change		
For each raw material and input, identify its environmental impacts and attributes. Consider such factors as: • durability • reusability • recycled content • energy or water efficiency • hazardous properties • contribution to hazardous by-products or waste • minimal packaging and/or reusable packaging • obtained from renewable resources		
For raw materials and inputs with significant environmental impacts, conduct research to identify environmentally preferable alternatives; involve suppliers in this research		
Determine whether legislation restricts the types of raw materials and inputs that can be used		
Develop internal green purchasing policy and program; this may include setting specific objectives and targets, establishing input specifications, creating a list of approved products, or requiring suppliers to meet certain conditions		
Train purchasing staff and other affected staff (such as receiving, inventory management) on new requirements		
Communicate new requirements to suppliers; maintain regular communication on environmental issues		
Develop performance indicators to measure the success of specific initiatives, and monitor progress toward targets		
Establish a formal review mechanism to: • evaluate the success of measures taken • identify new measures • provide feedback from the review to all employees		

Appendix I: On-Site Reuse and Recycling

Introduction

On-site reuse and recycling represent important and fairly well-understood pollution prevention practices. This information sheet introduces the key aspects of these practices and provides a checklist to help implement them.

Pollution prevention is "the use of processes, practices, materials, products, substances or energy that avoid or minimize the creation of pollutants and waste, and reduce the overall risk to the environment and human health" (*Canadian Environmental Protection Act, 1999*). Pollution prevention is at the top of a hierarchy of environmental protection methods that also include off-site reuse and recycling, pollution control or treatment, disposal/destruction, remediation and clean-up. While all environmental protection methods provide some benefits, pollution prevention can provide the most cost-effective opportunities for reducing environmental and health risks while improving a business's bottom line.

On-site reuse and recycling cover the processes of reusing and recycling at the same place where an activity has been conducted (as opposed to off-site). Reuse is the re-employment of products or materials, in their original form or in new applications, with refurbishing to original or new specifications as required. Recycling is the extension of the effective life span of renewable and non-renewable resources through changes to processes or practices and the addition of energy inputs. When it is conducted in an environmentally sound manner, recycling is preferable to end-of-pipe treatment. In some cases, on-site reuse and recycling is referred to as "by-product recovery."

Non-product outputs should be viewed as a loss of valuable process materials that, when reused or recycled, could have significant environmental or economic benefits.

Identifying Reuse and Recycling Opportunities

On-site reuse and recycling for pollution prevention are generally applicable in both small and large industries. Manufacturing and processing industries with significant waste production and water use, or with waste that is a valuable by-product (such as silver from photo processing), may achieve greater pollution prevention and economic benefits. The practice may be less applicable to small companies with small amounts of waste, where on-site recovery is not as cost-effective or where recovered material cannot be reused in the production process.

Separation/Segregation Techniques

In order for wastes to be usable for on-site recycling or reuse, they must first be separated from the process stream. There are several groups of separation technologies. For ease of discussion, these techniques can be divided into solid-solid streams, solid-liquid streams, liquid-gas streams, and solid-gas streams:

- To separate wastes in the solid phase, technologies such as screening, magnetic separation and air classification may be used.
- To remove wastes in the liquid phase, pH adjustment and precipitations, ion exchange, reverse osmosis, diffusion dialysis and electrodialysis, micro and ultra filtration, dewatering, extraction and electrolytic methods may be applied.
- Finally, to separate wastes in the gaseous phase, adsorption, membranes, absorption, cryogenics and condensation may be used.

A waste segregation technique commonly used by printers and metal fabricators is to collect and store wash water or solvents used to clean equipment (e.g., tanks, pipes, pumps, presses) for reuse in the production process. Some printing firms segregate and collect toluene used for press and roller cleaning. By segregating this toluene by colour and ink contaminant, companies can reuse it later for thinning. Recovery of 100% of the waste toluene totally eliminates a hazardous waste stream and reduces input costs.

To further increase the recoverability of specific wastes, it is often necessary to separate toxic, hazardous or recoverable wastes from the total waste stream. Applicable techniques range from simple segregation to complex concentration technology. Concentration techniques usually remove a component of the waste such as water. Available methods include gravity and vacuum filtration, reverse osmosis, freeze vaporization, filter press, heat drying and compaction.

At-source separation and the separate handling of hazardous and non-hazardous waste can reduce both waste volume and handling costs.

At Colgate-Palmolive Canada in Edmonton, all excess plastic removed from bottles after moulding is reground and reused in making new bottles. The plant uses about 25% in-house reground plastic in new bottles. Product drainage and rinses from product changeover clean-outs are collected in tote tanks and reused as process water in manufacturing new product. These recycling and other pollution prevention actions have reduced waste by an estimated 75%, despite increased production, and have yielded savings of approximately $25,000 in raw materials and reduced treatment chemicals.

Source: www.ec.gc.ca/pp/en/storyoutput.cfm?storyID=13

One of the best and most efficient places to recover process wastes is in the production facility at the point of generation (e.g., where granular material has spilled from a feed hopper, or where flashing is trimmed from moulded products). Here, the possibility of contamination by other material is lower, and the risks and cost of handling and transporting the recovered materials should be minimal.

Purification

Following recovery, some waste may have to be purified before it is reused or recycled. Purification can be achieved using readily available physical or chemical techniques including simple filtration, ion exchange, electrowinning, metal salt reclamation (chilling), atmospheric evaporation, distillation, reverse osmosis and freeze crystallization. Most on-site recovery systems produce some type of residue – the contaminants removed from the recovered material. The residue can then be processed for further recovery or properly disposed of.

Reuse and Recycling Methods

Table I1 illustrates potential sources and types of waste from various industrial operations, together with possible reuse and recycling methods. The methods are not limited to the waste origins and waste types they appear beside.

Wastewater Recycling

When wastewater is recycled (as opposed to reused), it is not treated but used directly in another application. Opportunities for recycling industrial wastewater are many, but depend on the water quality requirements of the receiving process.

Examples of potential industrial wastewater recycling applications include:

- **Cooling tower blowdown** recycled for wash water, utility water, flare drum seal water, pump coolant, tank field waste or scrubber water makeup

Table I1: Potential Reuse and Recycling Methods

Waste Source	Waste Types	Reuse/Recycling Methods
Materials receiving	Packaging materials, off-spec materials, damaged containers, spill residues, residues from transfer hose emptying	• Develop running inventory of unused chemicals for other departments' use • Conduct periodic materials tracking • Find uses for off-spec material that would otherwise be disposed of • Change to reusable shipping containers • Use rinseable or recyclable drums
Raw material and product storage	Tank bottoms, off-spec and excess materials, spill residues, leaking pumps, valves, tanks and pipes, damaged containers, empty containers	• Use vapour recovery system • Empty drums and containers thoroughly before cleaning or disposal • Find uses for off-spec material that would otherwise be disposed of • Use scrap paper for notepads; recycle paper
Laboratories	Reagents, off-spec chemicals, empty sample and chemical containers	• Find less critical uses for off-spec material that would otherwise be disposed of • Reuse/recycle spent solvents • Recover metal from catalysts
Operation and process changes	Production line drips, leaks, spills, drainage and rinses, solvents, cleaning agents, degreasing sludges, sandblasting waste, caustic scrap metal, oils, greases from equipment cleaning, sludge and spent acid from heat exchanger cleaning	• Reuse uncontaminated collected materials • Recycle rinsewater for countercurrent rinsing • Recycle lube oils • Recycle waste ink • Clean and reuse rags • Recover "drag-out" material • Recover reusable chemicals and valuable metals from waste stream (e.g., silver from printing plants) • Collect drips with drain boards • Collect and reuse clean-up solvent • Reprocess clean-up solvent into useful products • Keep individual hazardous waste streams segregated; segregate hazardous waste from non-hazardous waste; segregate recyclable waste from non-recyclable waste; segregate recyclables by type • Use squeegees to recover residual fluid on product prior to rinsing • Provide sufficient drain time for liquids

Textron Automotive Company in Port Hope, Ontario, saves about $77,000 a year in water costs due to in-plant reuse and recycling of cooling water from injection moulding machines.

Source: www.ec.gc.ca/pp/en/storyoutput.cfm?storyID=43

- **Boiler blowdown** recycled for lower-pressure boiler makeup water
- **Rinsewater** recycled for countercurrent rinsing
- **Once-through cooling water** recycled for cooling pond, compressor cooling water, non-contact cooling water, or process water
- **Condensate from tanks or processes** recycled for boiler makeup water

A waste segregation technique commonly used by printers and metal fabricators is to collect and store wash water or solvents used to clean equipment (e.g., tanks, pipes, pumps, presses) for reuse in the production process. Some printing firms segregate and collect toluene used for press and roller cleaning. By segregating this toluene by colour and ink contaminant, companies can reuse it later for thinning. Recovery of 100% of the waste toluene totally eliminates a hazardous waste stream and reduces input costs.

To further increase the recoverability of specific wastes, it is often necessary to separate toxic, hazardous or recoverable wastes from the total waste stream. Applicable techniques range from simple segregation to complex concentration technology. Concentration techniques usually remove a component of the waste such as water. Available methods include gravity and vacuum filtration, reverse osmosis, freeze vaporization, filter press, heat drying and compaction.

At-source separation and the separate handling of hazardous and non-hazardous waste can reduce both waste volume and handling costs.

At Colgate-Palmolive Canada in Edmonton, all excess plastic removed from bottles after moulding is reground and reused in making new bottles. The plant uses about 25% in-house reground plastic in new bottles. Product drainage and rinses from product changeover clean-outs are collected in tote tanks and reused as process water in manufacturing new product. These recycling and other pollution prevention actions have reduced waste by an estimated 75%, despite increased production, and have yielded savings of approximately $25,000 in raw materials and reduced treatment chemicals.

Source: www.ec.gc.ca/pp/en/storyoutput.cfm?storyID=13

One of the best and most efficient places to recover process wastes is in the production facility at the point of generation (e.g., where granular material has spilled from a feed hopper, or where flashing is trimmed from moulded products). Here, the possibility of contamination by other material is lower, and the risks and cost of handling and transporting the recovered materials should be minimal.

Purification

Following recovery, some waste may have to be purified before it is reused or recycled. Purification can be achieved using readily available physical or chemical techniques including simple filtration, ion exchange, electrowinning, metal salt reclamation (chilling), atmospheric evaporation, distillation, reverse osmosis and freeze crystallization. Most on-site recovery systems produce some type of residue – the contaminants removed from the recovered material. The residue can then be processed for further recovery or properly disposed of.

Reuse and Recycling Methods

Table 11 illustrates potential sources and types of waste from various industrial operations, together with possible reuse and recycling methods. The methods are not limited to the waste origins and waste types they appear beside.

Wastewater Recycling

When wastewater is recycled (as opposed to reused), it is not treated but used directly in another application. Opportunities for recycling industrial wastewater are many, but depend on the water quality requirements of the receiving process.

Examples of potential industrial wastewater recycling applications include:

- **Cooling tower blowdown** recycled for wash water, utility water, flare drum seal water, pump coolant, tank field waste or scrubber water makeup

Table I1: Potential Reuse and Recycling Methods

Waste Source	Waste Types	Reuse/Recycling Methods
Materials receiving	Packaging materials, off-spec materials, damaged containers, spill residues, residues from transfer hose emptying	• Develop running inventory of unused chemicals for other departments' use • Conduct periodic materials tracking • Find uses for off-spec material that would otherwise be disposed of • Change to reusable shipping containers • Use rinseable or recyclable drums
Raw material and product storage	Tank bottoms, off-spec and excess materials, spill residues, leaking pumps, valves, tanks and pipes, damaged containers, empty containers	• Use vapour recovery system • Empty drums and containers thoroughly before cleaning or disposal • Find uses for off-spec material that would otherwise be disposed of • Use scrap paper for notepads; recycle paper
Laboratories	Reagents, off-spec chemicals, empty sample and chemical containers	• Find less critical uses for off-spec material that would otherwise be disposed of • Reuse/recycle spent solvents • Recover metal from catalysts
Operation and process changes	Production line drips, leaks, spills, drainage and rinses, solvents, cleaning agents, degreasing sludges, sandblasting waste, caustic scrap metal, oils, greases from equipment cleaning, sludge and spent acid from heat exchanger cleaning	• Reuse uncontaminated collected materials • Recycle rinsewater for countercurrent rinsing • Recycle lube oils • Recycle waste ink • Clean and reuse rags • Recover "drag-out" material • Recover reusable chemicals and valuable metals from waste stream (e.g., silver from printing plants) • Collect drips with drain boards • Collect and reuse clean-up solvent • Reprocess clean-up solvent into useful products • Keep individual hazardous waste streams segregated; segregate hazardous waste from non-hazardous waste; segregate recyclable waste from non-recyclable waste; segregate recyclables by type • Use squeegees to recover residual fluid on product prior to rinsing • Provide sufficient drain time for liquids

Textron Automotive Company in Port Hope, Ontario, saves about $77,000 a year in water costs due to in-plant reuse and recycling of cooling water from injection moulding machines.

Source: www.ec.gc.ca/pp/en/storyoutput.cfm?storyID=63

- **Boiler blowdown** recycled for lower-pressure boiler makeup water
- **Rinsewater** recycled for countercurrent rinsing
- **Once-through cooling water** recycled for cooling pond, compressor cooling water, non-contact cooling water, or process water
- **Condensate from tanks or processes** recycled for boiler makeup water

Opportunities for recycling sanitary wastewater are more limited. Grey wastewater from bathing, washing machines and dishwashers can be recycled for toilet flushing. Often, shower and laundry wastewaters can be used for irrigation.

Reusing Treated Wastewater

Wastewater can be treated and reused depending on such factors as the required quality of the reused wastewater and the existence of a cost-effective treatment technology to return the water to the required quality. Example treatment technologies are listed in Table I2.

Opportunities to reuse treated wastewater on-site may include:

- landscape irrigation for lawn areas;
- industrial reuse as cooling tower makeup water, once-through cooling water, boiler feed water, process water;
- groundwater recharge for groundwater replenishment, saltwater intrusion control, subsistence control;
- recreational/environmental uses including lakes and ponds, marsh enhancement, stream flow augmentation, fisheries, snow making;
- non-potable urban uses such as fire protection, air-conditioning, toilet flushing; and
- potable uses such as blending in water supply, reservoir, pipe-to-pipe water supply.

Key Steps

Establish Responsibility

Making these changes requires a "champion." Be sure to clearly assign overall responsibility for identifying and implementing reuse and recycling opportunities. Particularly because such opportunities may be identified at numerous locations in a plant or points in a process, a team approach will help to share relevant information. The team should include a representative from each of the following areas: purchasing; research, design and development; shipping and receiving; industrial engineering; production; marketing; maintenance; and environment, health and safety.

Baseline Review

The baseline review entails a careful review of all inputs, outputs and non-product outputs related to the current production processes. This should include all aspects of the process from raw materials delivery through each production

Table I2: Example Treatment Technologies for Wastewater Reuse

Technology	Application
Reverse osmosis	Removal of BOD[1], COD[2], TDS[3], TSS[4], NH_3[5] and phosphorus
Electrodialysis	Removal of TDS and recovery of metal salts
Ultrafiltration	Removal of TDS, turbidity and oil
Ion exchange	Removal of TDS and toxic metal ions; reduction of hardness
Activated carbon	Removal of many organic and inorganic compounds
Sedimentation	Removal of solids denser than water
Filtration	Dewatering sludges; removal of suspended solids; pre-treatment
Evaporation	Treatment of hazardous and solvent wastes; separation of suspended and dissolved solids
pH adjustment and precipitation	Removal of metals in the form of metal salts from metal processing acid wastes; neutralization of waste acids and bases in various industries
Dewatering	Reducing moisture content of sludges

[1] BOD: biological oxygen demand

[2] COD: chemical oxygen demand

[3] TDS: total dissolved solids

[4] TSS: total suspended solids

[5] NH_3: ammonia

step and each source of waste to final product storage. This review is similar to those done for other pollution prevention practices and, ideally, should be combined with them.[1] This review should identify current material flows and identify various opportunities for reuse or recycling.

Select Options and Establish an Implementation Plan, Targets and Indicators

Once the team selects measures to implement, it should develop an implementation plan including specific performance targets and indicators. These should be consistent with any broader objective or target established within the organization's environmental management system (EMS) or pollution prevention plan.

Provide Training

Staff must be trained in any new requirements, including the rationale for the changes, and their role in implementing them. They should also have written materials summarizing the changes for future reference.

Review and Evaluate

On a regular basis, the organization should monitor and evaluate progress toward implementing specific action items and meeting established targets. The team should examine the root cause of any deviations from the action plan or failure to achieve targets or specific milestones and determine what corrective action, if any, should be implemented.

Through on-site water reuse and recycling and an on-site evaporation pond, Saskferco Products in Saskatchewan significantly reduced water use and eliminated wastewater discharges to local waterways. The reuse/recycling techniques adopted include the reuse of steam turbine condensate as boiler or cooling water, purification and reuse of steam condensate from the process gas and extensive recycling of process and cooling water.

Source: www.pnr-rpn.ec.gc.ca/pollution/e00s60.en.html

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[1] For more information on conducting a baseline review to identify pollution prevention opportunities, please refer to Appendix B, "Key Elements of a Baseline Review."

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References and Resources

For more information on pollution prevention and pollution prevention planning:

Canadian Pollution Prevention Information Clearinghouse: www.ec.gc.ca/cppic

Canadian Centre for Pollution Prevention: www.c2p2online.com

Canadian Environmental Protection Act, 1999: www.ec.gc.ca/CEPARegistry

Your Environment Canada Regional Office.

For more information on on-site reuse and recycling:

Freeman, Harry M. 1995. *Industrial Pollution Prevention Handbook*. McGraw-Hill

Higgins, Thomas E. 1995. *Pollution Prevention Handbook*. CRC Press Inc.

U.S. Navy, Naval Facilities Engineering Service Center. "Joint Service Pollution Prevention Opportunity Handbook": www.enviro.nfesc.navy.mil/p2library/cgi-bin/index_opp.cfm

Ohio Environmental Protection Agency, Office of Pollution Prevention, Fact Sheet Number 9: "On-Site Solvent Recycling Equipment": www.epa.state.oh.us/opp/solvents/fact9.html

Checklist for On-Site Reuse and Recycling

Task	Responsibility	Completion Date
Assign overall responsibility for on-site reuse and recycling to management a representative		
Establish a cross-functional team		
Map out material flows and process steps		
For each process step, identify: • what happens, including cleaning and maintenance • type, quantity and cost of inputs • material and energy losses and waste generated • how each non-product output is disposed of and disposal costs		
Overall, and for each process step, identify, evaluate and, where appropriate, select measures to enable further recycling or reuse of non-product outputs		
Develop an implementation plan for selected measures		
Establish performance targets		
Provide staff training		
Develop performance indicators to measure the success of specific initiatives, and monitor progress against targets		
Establish a formal review mechanism to: • evaluate the success of measures taken • identify new measures • provide feedback from the review to all employees		